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FINAL REPORT

SPACELAB USER IMPLEMENTATION ASSESSMENT STUDY

Volume IV

SUIAS Appendixes

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LANGLEY RESEARCH CENTER
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Space Division
Rockwell International

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FOREWORD

The Spacelab User Implementation Assessment Study was conducted to assess and minimize the capital investment of the National Aeronautics and Space Administration for the integration and checkout of Spacelab payloads such as Langley's Advanced Technology Laboratory. The study was conducted by the Space Division of Rockwell International Corporation under Contract NAS1-12933 for the Langley Research Center. Mr. F. O. Allamby was the technical study manager for the Langley Research Center. In addition, this study received agency-wide guidance and evaluation from the Steering Group for Payloads Operations Concept Studies, directed by Mr. W. O. Armstrong, to maximize the objectivity and applicability of the study data.

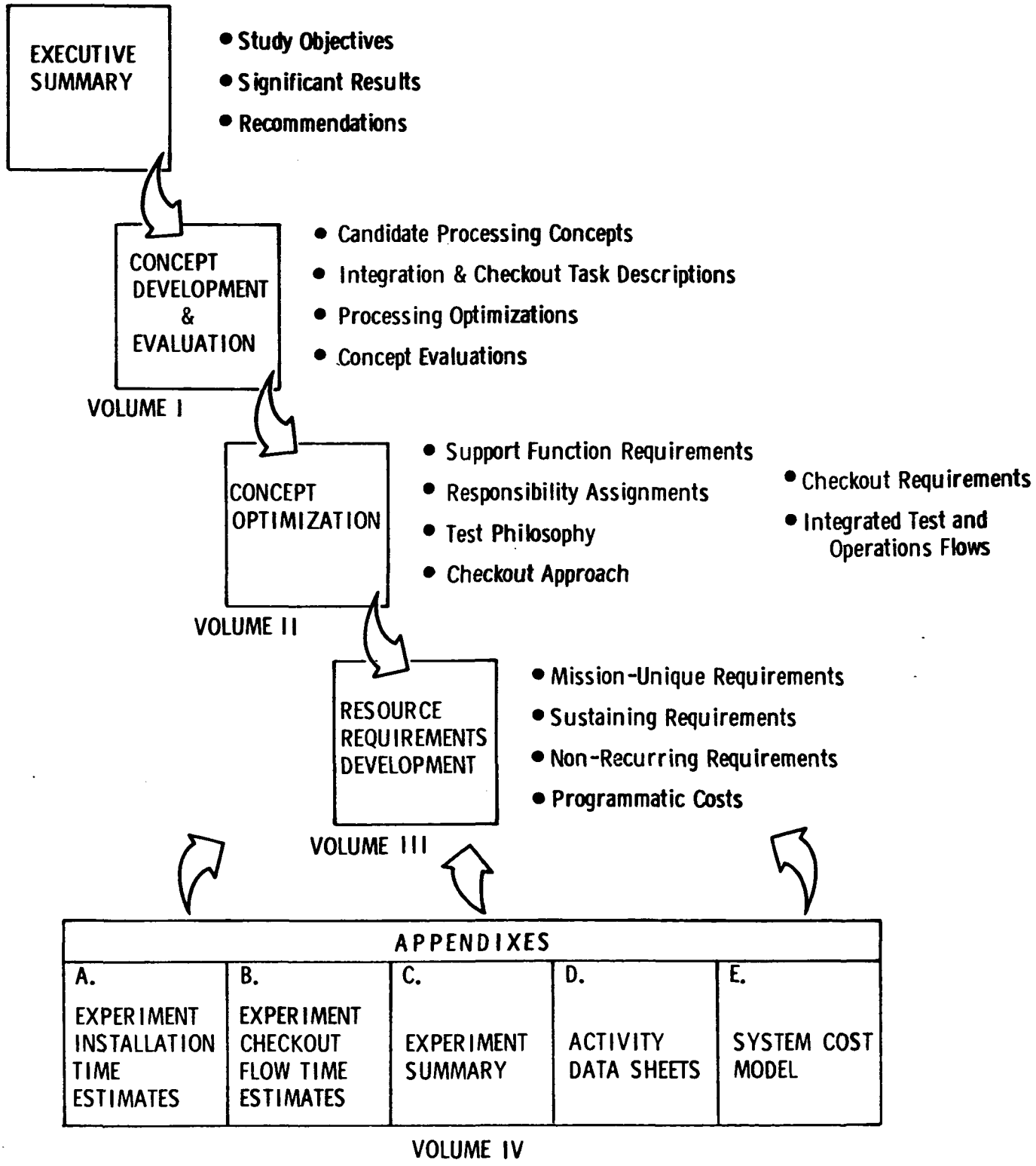
The final report consists of an executive summary and four technical volumes as illustrated in the accompanying figure. A succinct summary of the study is presented in the executive summary. Three of the four technical volumes present the analyses and trades performed during the course of the study. The fourth volume contains five appendixes, which delineate detailed data pertaining to the installation and checkout of Spacelab payloads such as the ATL, and a computer cost model utilized in the compilation of programmatic resource requirements. The contents of the volumes are described below.

EXECUTIVE SUMMARY

- Study overview--objectives, study approach.
- Synopsis of development of candidate processing concepts--complete Spacelab and pallet-only configurations.
- Summary of integration and checkout optimizations--checkout approach, ground operations processing cycle, personnel, ground support equipment and facility requirements.
- Programmatic costing--mission-unique, sustaining, and non-recurring cost estimates for required personnel, material, travel, documentation, ground support equipment, and facilities.
- Concept evaluations--flight-rate sensitivities and concept applicabilities.

VOLUME I. CONCEPT DEVELOPMENT AND EVALUATION

- Complete Spacelab processing concept development.
- Pallet-only processing concept development.



Study Reports

- Results of study optimizations in the areas of checkout requirements, simulator utilization, and configurational changes.
- Flight-rate sensitivities--flight hardware, GSE, facility, and personnel.
- Concept evaluations--integration center/launch site co-location, support module cognizance, WTR implications, general applicability, recommended ATL approach.

VOLUME II. CONCEPT OPTIMIZATIONS

- Supporting functions--development, definitions, and responsibility assignments. Identifies potential software applications.
- Test requirements--checkout approach and requirements, test philosophy, and environmental test requirements.
- Test and operations sequence--development of functional flows, detailed operations, activity data sheets, and integrated flows for both the complete Spacelab and pallet-only processing concepts.

VOLUME III. RESOURCE REQUIREMENTS DEVELOPMENT

- Requirements for mission-unique, sustaining, and non-recurring resources--includes personnel, travel, transportation, material, documentation, GSE, and facilities.
- Programmatic costing--presents cost estimates for all resource requirements.
- Cost-risk analysis--parametric evaluation of deletion of vibra-acoustic, thermal-vacuum and repeat functional tests.

VOLUME IV. APPENDIXES A, B, C, D, AND E

- *Appendix A. Experiment Installation Time Estimates* - Time estimates of the required experiment installation activities including (1) physical installation of experiment hardware in a rack, igloo, or on a pallet; (2) performance of electrical bonding checks; (3) complete mechanical interconnection including fluid and electrical lines; and (4) performance of end-to-end continuity checks between the experiment connector and the interface connector at the experiment module/pallet, support module/experiment module or igloo interfaces.
- *Appendix B. Experiment Checkout Flow Time Estimates* - The general experiment checkout flow plus the time estimates for

each individual experiment in the ATL experiment complement. These time estimates detail the time required for:

- Equipment setup and activation, including controls and display equipment.
- Verification of the operation of mechanical devices of both pallet and rack-mounted sensors and auxiliary equipment.
- Verification of data processing/recording equipment and instrumentation concurrent with checkout of the experiments.

- *Appendix C. Experiment Summary* - A summary of the requirements and equipment utilized for each experiment included in the study. The experiments are listed by discipline.
  - Navigation
  - Earth Observations
  - Physics and Chemistry
  - Microbiology
  - Environmental Effects
  - Components and Systems Testing

  The summary for each experiment includes the objectives or purpose, the description of the equipment utilized, the operation of the equipment, and the physical parameters of mass properties and equipment installation location (pallet, rack, igloo).

- *Appendix D. Activity Data Sheets* - Detailed definitions of the test operations associated with each activity defined in the expanded functional blocks (detailed functional flows). The activity data sheets describe the operations involved and the resources utilized to accomplish the processing cycle. They cover the entire cycle from initial experiment installation through the various integration levels (Experiment, III; Spacelab, II; Orbiter Cargo, I), and the refurbishment of the pallets, racks and/or igloos, following the completion of the mission.

- *Appendix E. System Cost Model* - Description of computer cost model utilized in the study to compile the derived resource requirements into mission-unique, sustaining, and non-recurring cost categories.

Within each volume, the term "concept" is used repeatedly and data are presented with respect to Concepts I through VIII. The concepts referred to pertain to alternate integration and checkout approaches for both the complete Spacelab (support module, experiment module, and pallet) and the pallet-only Spacelab configuration. The following two tables define, in general terms, each of the eight processing concepts that were definitized in this study.

Complete Spacelab Processing Concepts

Concept	Owner			Integration Site	
	Support Module	Experiment Module	Pallet	Experiment Equipment	Spacelab
I	IC	IC	IC	IC	IC
II	LS	IC	IC	IC	LS
III	LS	IC	IC	User	LS
IV	LS	User	User	User	LS
V	User	User	User	User	User

Pallet-Only Processing Concepts

Concept	Owner		Integration Site	
	Pallet	Igloo*	Experiment Equipment	Spacelab
VI	IC	LS	User	LS
VII	IC	LS	IC	LS
VIII	User	LS	User	LS

*Support system igloo and equipment

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12.0	(REFERENCE MISSION)	N/A
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A. EXPERIMENT INSTALLATION TIME ESTIMATES

APPENDIX A
EXPERIMENT INSTALLATION TIME ESTIMATES

Appendix A is the detailed time estimates of the required installation activities. To facilitate their use in other study activities, these estimates have been grouped by payload. The following assumptions were made concerning the experiment module racks and igloo plus the pallet.

1. Racks have been previously refurbished and reconfigured. All experiment equipment from previous flights has already been removed.

2. The rack is accessible from all sides for equipment installation.

3. The pallet is an open framework which has already been stripped of previous flight equipment.

4. The necessary mounting brackets, cables and wire runs required for each experiment have previously been installed.

The installation times listed for each experiment are the times required to accomplish the following.

1. Physically install the new experiment hardware package in a rack, igloo, or on a pallet.

2. Perform an electrical bonding check of completed mechanical connections.

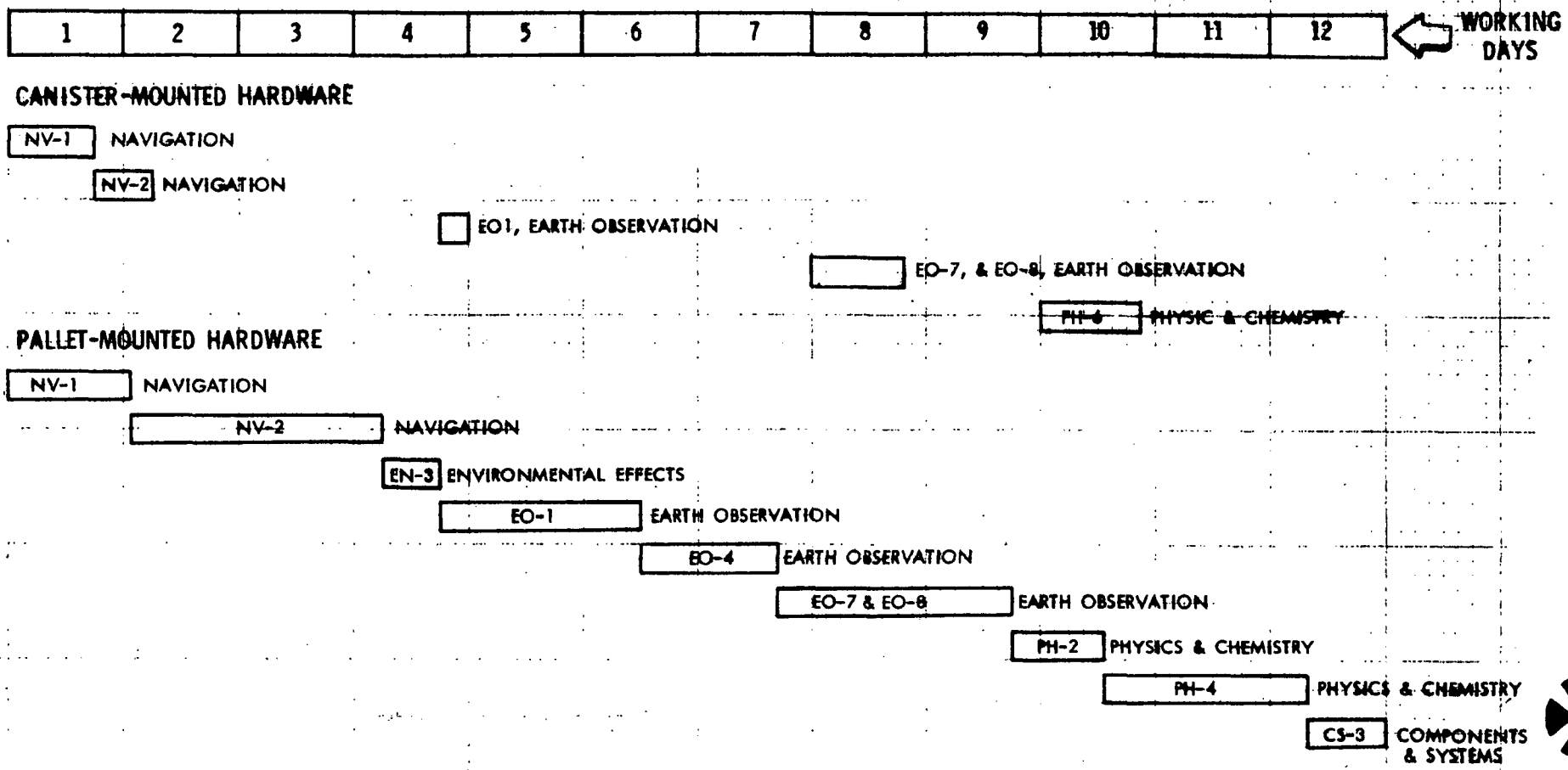
3. Complete mechanical installation and tiedown, including connection of fluid (coolant loop) lines.

4. Perform an end-to-end continuity check of the wiring between the experiment connector and the interface connector at the experiment module/pallet (EM/P), support module/experiment module (SM/EM), or igloo interface.

The experiment complement for the three missions utilized in the SUIAS study are defined in Table A-1. Mission 1 utilizes a 50-foot (approximate) pallet and igloo (non-habitable volume) in the cargo bay. Experiment support equipment for this payload configuration is located either in the Orbiter or in the pallet-mounted igloo. Missions 2 and 3 utilize the Spacelab installed in the cargo bay as an integral unit. The experiment support equipment for these two concepts is installed in either the SM or EM.

Table A-1. ATL Payload Groupings

	Mission Number		
	1	2	3
NAVIGATION			
NV-1 Microwave Interferometer			X
NV-2 Autonomous Navigation			X
NV-3 Multipath Measurements	X		
EARTH OBSERVATIONS			
EO-1 Lidar Measurements			X
EO-2 Tunable Lasers	X		
EO-3 Multispectral Scanner		X	
EO-4 Microwave Radiometer			X
EO-5 Laser Ranging	X		
EO-6 Microwave Altimetry		X	
EO-7 Search and Rescue Aids			X
EO-8 Imaging Radar			X
EO-9 RF Noise	X		
PHYSICS AND CHEMISTRY			
PH-1 Wake Dynamics		X	
PH-2 Barium Cloud Release	X		X
PH-3 Aerosol Properties	X	X	
PH-4 Neutral Gas Parameters	X		X
PH-5 Radiation Environment	X		
PH-6 Meteor Spectroscopy		X	X
MICROBIOLOGY			
MB-1 Colony Growth	X	X	X
MB-2 Micro-Organism Transfer		X	
MB-3 Biological Cell Electrical Field Opacity	X		
MB-4 Bio Cell Electrical Characteristics		X	
MB-5 Bio Cell Properties		X	
ENVIRONMENTAL EFFECTS			
EN-1 Micro-Organism Sampling	X	X	X
EN-2 Material Fatigue		X	
EN-3 Non-Metallic Materials Degradation		X	X
COMPONENTS AND SYSTEMS			
CS-2 Zero-Gravity Steam Generator		X	
XST- Contamination Monitor	X	X	X



PAYLOAD 1 INSTALLATION FLOW

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NV-1 NAVIGATION EXPERIMENT

- INSTALLATION PREPARATIONS
- INSTALL WIRE HARNESS
- INSTALL ELECTRONICS
- INSTALL BUFFER
- INSTALL PHASE RECEIVERS
- CLOSE OUT & SECURE

NV-2 NAVIGATION EXPERIMENT

- INSTALLATION PREPARATIONS
- INSTALL WIRE HARNESS
- INSTALL COMPUTER
- CLOSE OUT & SECURE

EO-1, EARTH OBSERVATION EXPERIMENT

- INSTALLATION PREPARATIONS
- INSTALL WIRE HARNESS
- INSTALL DATA PROCESSING EQUIPMENT
- CLOSE OUT & SECURE

EO-7, -8 EARTH OBSERVATION EXPERIMENT

- INSTALLATION PREPARATIONS
- INSTALL WIRE HARNESS
- INSTALL FREQUENCY METER
- INSTALL ELECTRONICS (EO-7)
- INSTALL ELECTRONICS (EO-8)
- CLOSE OUT & SECURE

PH-6 PHYSICS & CHEMISTRY EXPMT

- INSTALLATION PREPARATIONS
- INSTALL WIRE HARNESS
- INSTALL SENSORS
- CLOSE OUT & SECURE

PAYLOAD 1 INSTALLATION

IGLOO-MOUNTED HARDWARE

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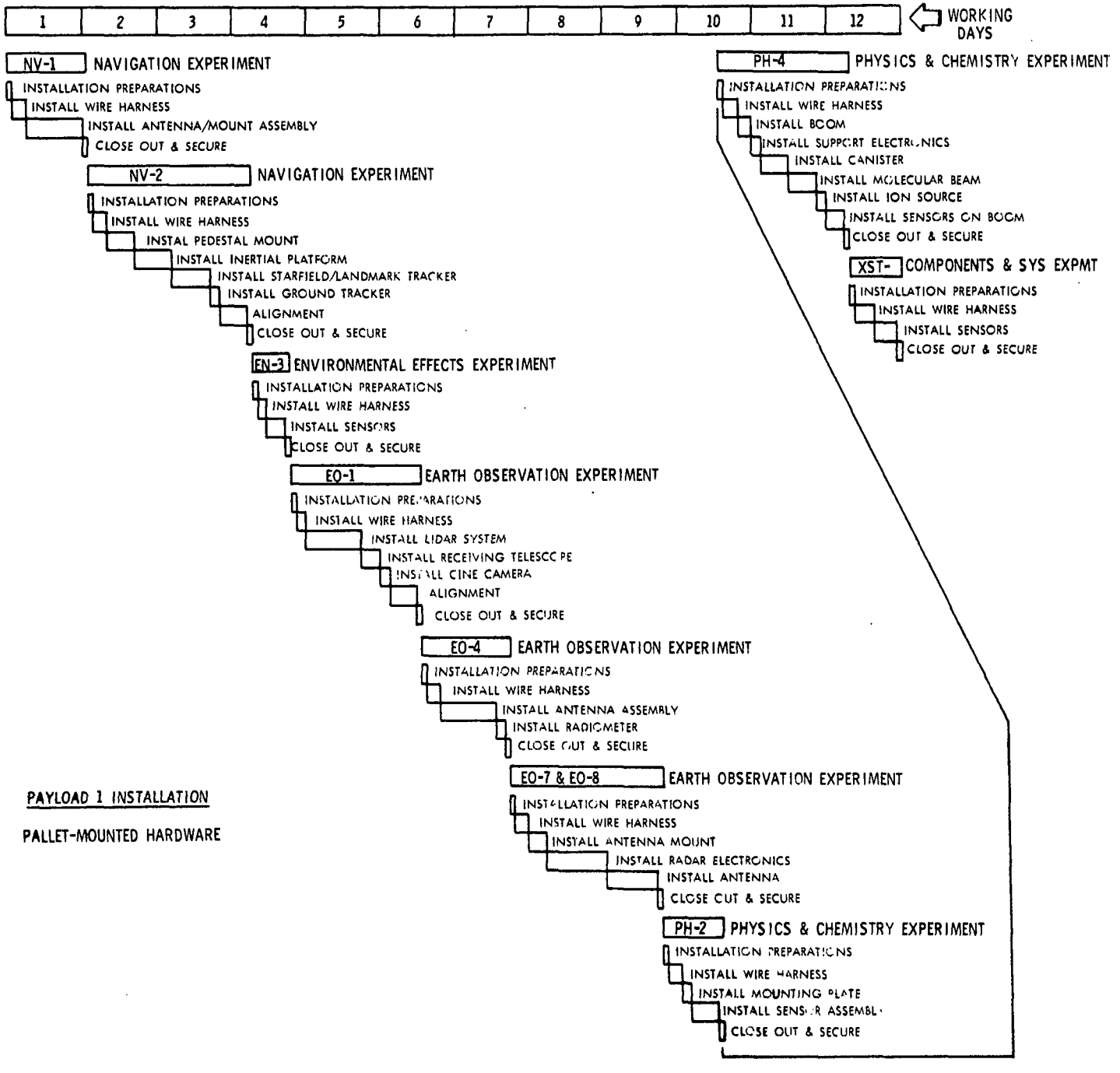

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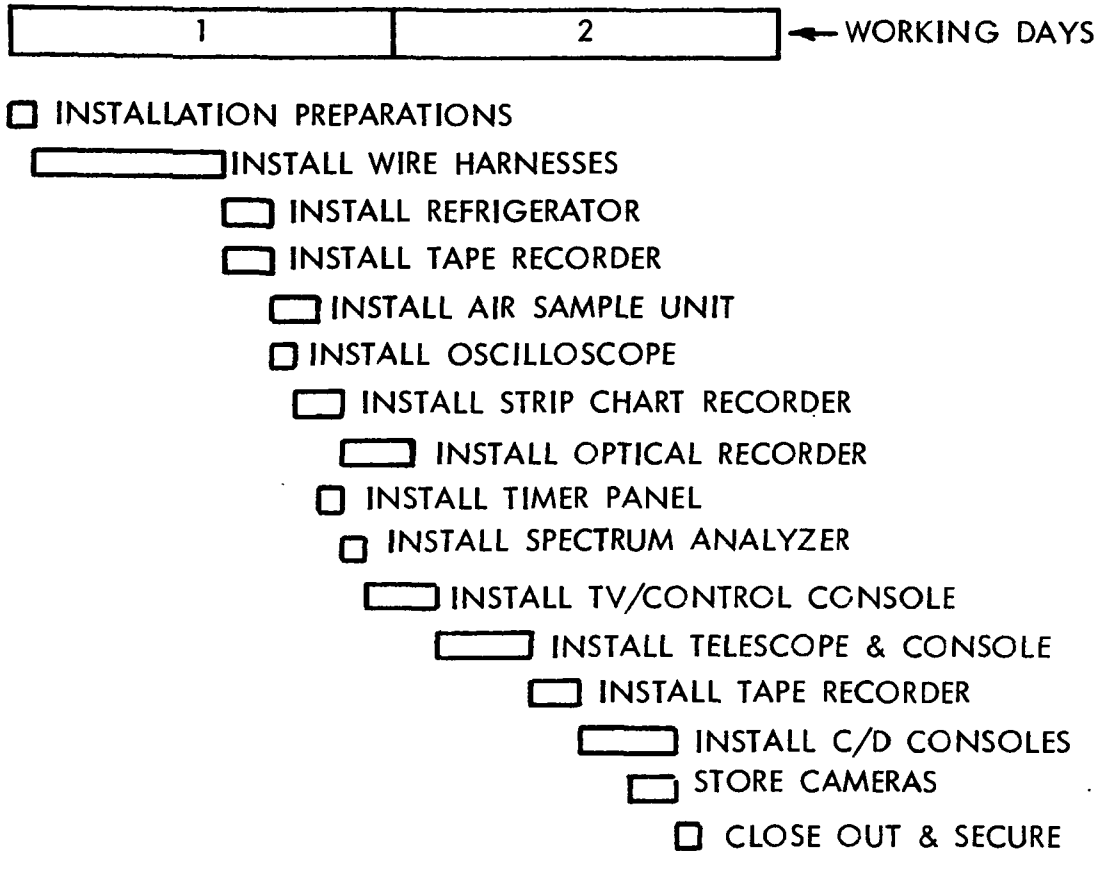
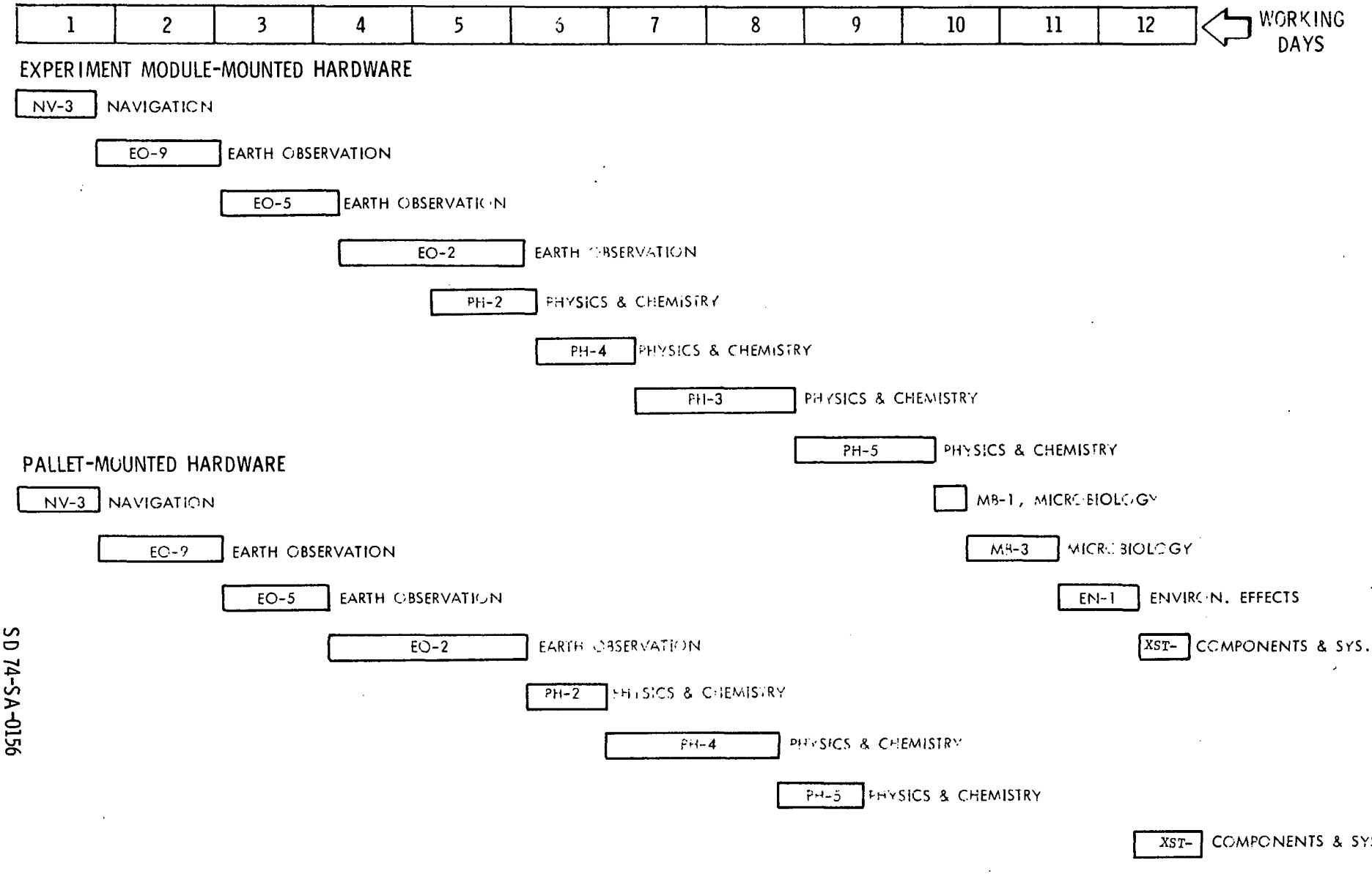


PAYLOAD 1 INSTALLATION

ORBITER (PSS) MOUNTED HARDWARE



PAYLOAD 2 INSTALLATION FLOW

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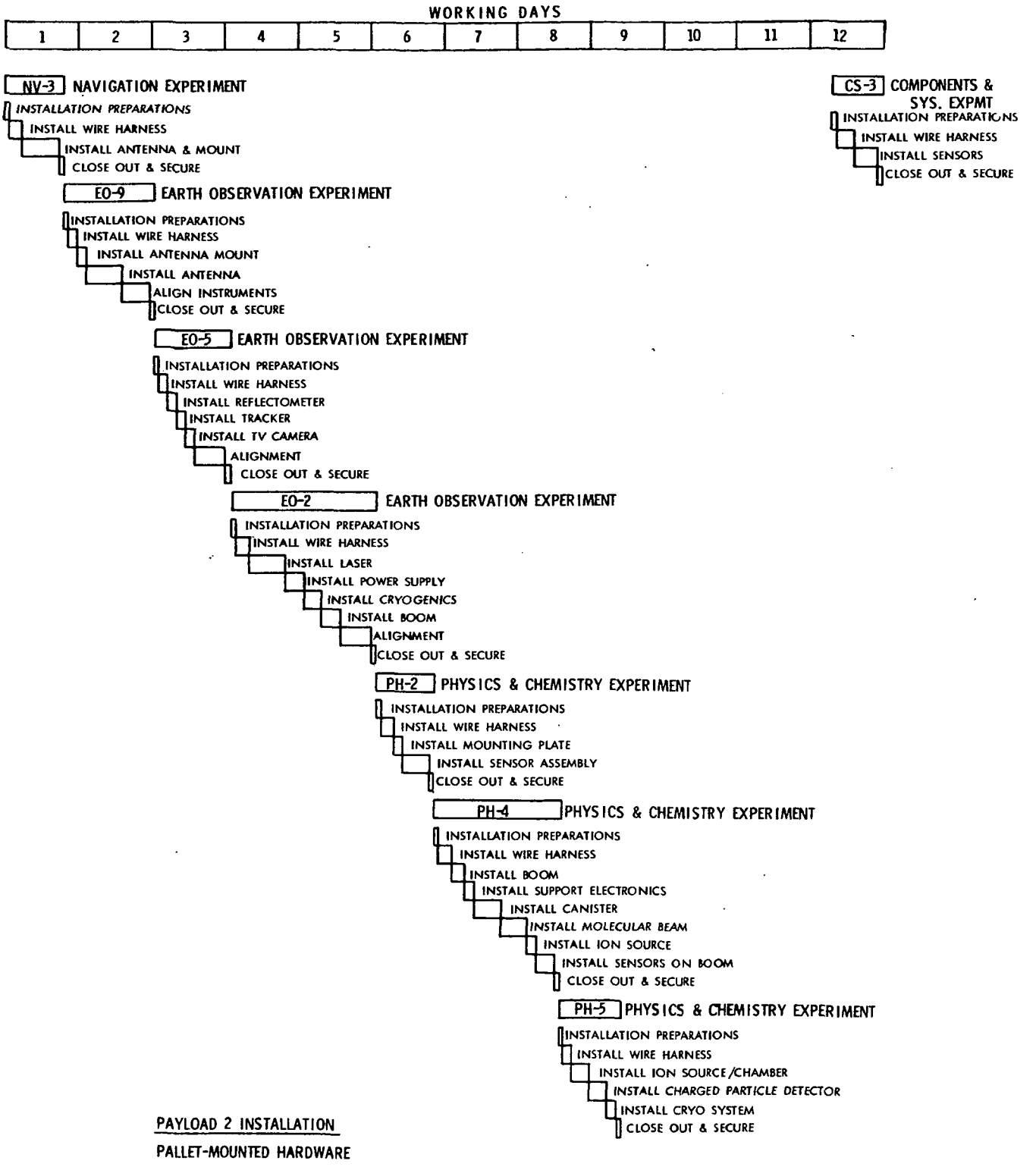
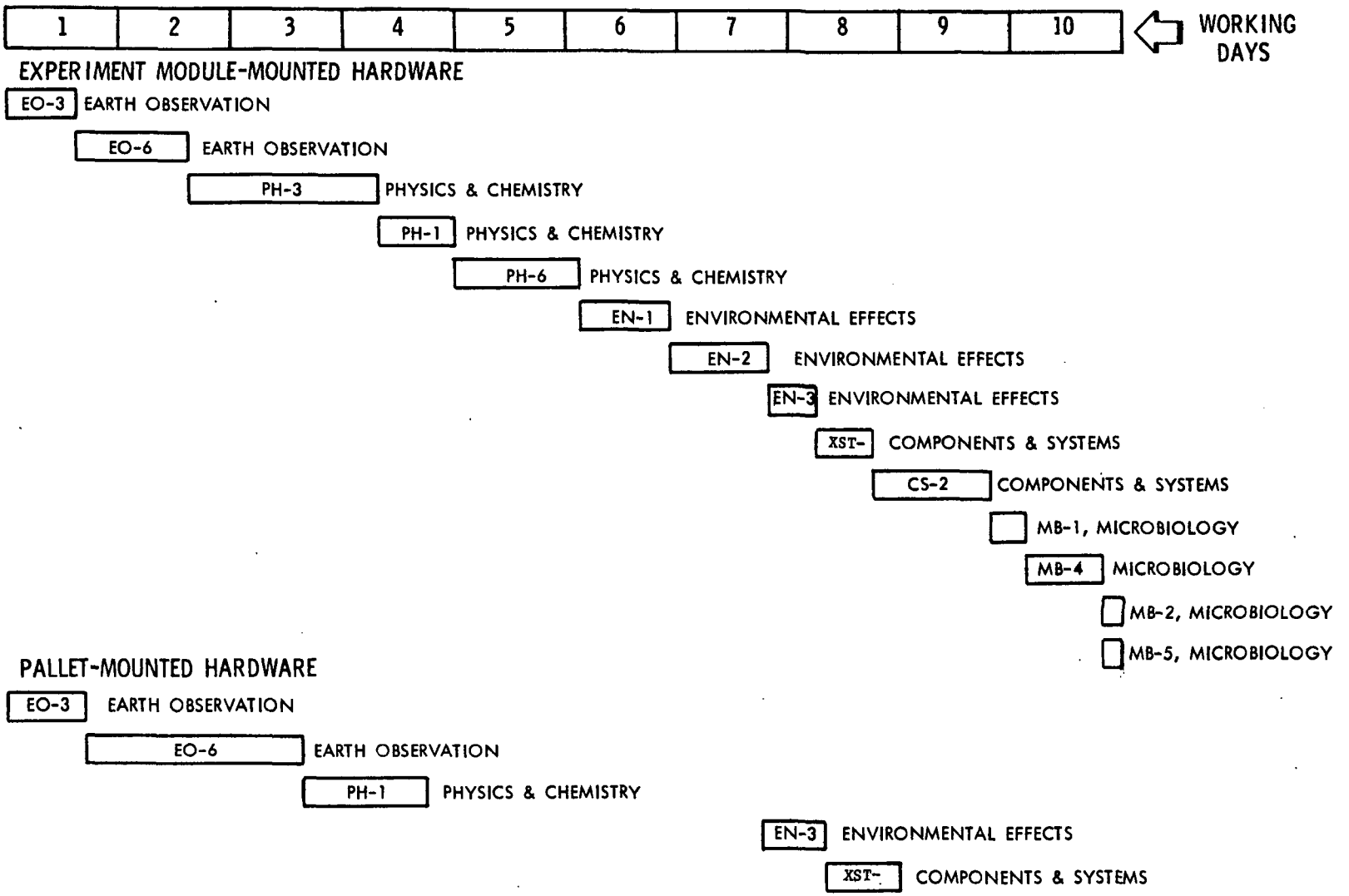
WORKING DAYS
1
2
3
4
5
6
7
8
9
10
11
12
NV-3 NAVIGATION EXPERIMENT
INSTALLATION PREPARATIONS
INSTALL WIRE HARNESS
INSTALL C/D CONSOLE
INSTALL ELECTRONICS
INSTALL RECEIVER
INSTALL TAPE RECORDER
CLOSE OUT & SECURE
EO-9 EARTH OBSERVATIONS EXPMT
INSTALLATION PREPARATIONS
INSTALL WIRE HARNESS
INSTALL C/D PANEL
INSTALL RECEIVER
INSTALL POWER SUPPLY
INSTALL TV MONITOR
INSTALL TV CAMERA
INSTALL TAPE RECORDER
ALIGNMENT
CLOSE OUT & SECURE
EO-5 EARTH OBSERVATIONS EXPMT
INSTALLATION PREPARATIONS
INSTALL WIRE HARNESS
INSTALL LASER
INSTALL ELECTRONICS
INSTALL C/D CONSOLE
ALIGNMENT
INSTALL TAPE RECORDER
INSTALL/STOW STILL CAMERA
CLOSE OUT & SECURE
EO-2 EARTH OBSERV EXPMT
INSTALLATION PREPARATIONS
INSTALL WIRE HARNESS
INSTALL C/D PANEL
INSTALL TELESCOPE
INSTALL TAPE RECORDER
ALIGNMENT
CLOSE OUT & SECURE
PH-2 PHYSICS & CHEMISTRY EXPMT
INSTALLATION PREPARATIONS
INSTALL WIRE HARNESS
INSTALL C/C CONSOLE
INSTALL POINTING TELESCOPE
STOW FRAMING CAMERA
CLOSE OUT & SECURE
PH-4 PHYSICS & CHEMISTRY EXPMT
INSTALLATION PREPARATIONS
INSTALL WIRE HARNESS
INSTALL C/D PANEL
INSTALL TAPE RECORDER
INSTALL COMPUTER
INSTALL OSCILLOSCOPE
INSTALL DATA PROCESSOR
CLOSE OUT & SECURE
PAYLOAD 2 INSTALLATION
EM-MOUNTED HARDWARE
PH-3 PHYSICS & CHEMISTRY EXPERIMENT
INSTALLATION PREPARATIONS
INSTALL WIRE HARNESS
INSTALL CONSOLE/CRYOGENICS
INSTALL AEROSOL/ION GENERATORS
INSTALL WATER VAPOR SOURCE
INSTALL ENVIRONMENTAL CHAMBER
INSTALL/STOW LIGHT SOURCES
MOUNT C/D PANEL
INSTALL INSTRUMENTATION SENSORS
STOW MICROSCOPE
STOW CINE CAMERA
STOW STILL CAMERA
CLOSE OUT & SECURE
PH-5 PHYSICS & CHEMISTRY EXPMT
INSTALLATION PREPARATIONS
INSTALL WIRE HARNESS
INSTALL CHARGED PARTICLE DETECTOR
INSTALL CRYO SYSTEM
INSTALL C/D CONSOLE
INSTALL GAMMA RAY SPECTROMETER
INSTALL NEUTRON SPECTROMETER
INSTALL ION CHAMBER
INSTALL LOGIC SYSTEM
INSTALL A/D CONVERTER
STORE FILM BADGES
STORE DOSIMETER
INSTALL SUPERVISOR SYSTEM
CLOSE OUT & SECURE
MB-1 MICROBIOLOGY EXPERIMENT
INSTALLATION PREPARATIONS
INSTALL REFRIGERATOR
STORE EXPERIMENT CONTAINER
CLOSE OUT & SECURE
MB-3 MICROBIOLOGY EXPMT
INSTALLATION PREPARATIONS
INSTALL WIRE HARNESS
INSTALL STORAGE COMPARTMENT
INSTALL INCUBATOR
INSTALL VOLUME SPECTROMETER
INSTALL COULTER COUNTER
INSTALL REFRIGERATOR
INSTALL ELECTRONIC SENSOR
STORE MICROSCOPE
STORE CAMERA
CLOSE OUT & SECURE
EN-1 ENVIRON. EFFECTS EXPMT
INSTALLATION PREPARATIONS
INSTALL WIRE HARNESS
INSTALL C/D CONSOLE
INSTALL REFRIGERATOR
INSTALL TIMER
INSTALL AIR SAMPLE UNITS
CLOSE OUT & SECURE
XST- COMPONENTS & SYS. EXPMT
INSTALLATION PREPARATIONS
INSTALL WIRE HARNESS
INSTALL C/D PANEL
CLOSE OUT & SECURE


WORKING DAYS
1
2
3
4
5
6
7
8
9
10
11
12
NV-3 NAVIGATION EXPERIMENT
INSTALLATION PREPARATIONS
INSTALL WIRE HARNESS
INSTALL ANTENNA & MOUNT
CLOSE OUT & SECURE
CS-3 COMPONENTS & SYS. EXPMT
INSTALLATION PREPARATIONS
INSTALL WIRE HARNESS
INSTALL SENSORS
CLOSE OUT & SECURE
EO-9 EARTH OBSERVATION EXPERIMENT
INSTALLATION PREPARATIONS
INSTALL WIRE HARNESS
INSTALL ANTENNA MOUNT
INSTALL ANTENNA
ALIGN INSTRUMENTS
CLOSE OUT & SECURE
EO-5 EARTH OBSERVATION EXPERIMENT
INSTALLATION PREPARATIONS
INSTALL WIRE HARNESS
INSTALL REFLECTOMETER
INSTALL TRACKER
INSTALL TV CAMERA
ALIGNMENT
CLOSE OUT & SECURE
EO-2 EARTH OBSERVATION EXPERIMENT
INSTALLATION PREPARATIONS
INSTALL WIRE HARNESS
INSTALL LASER
INSTALL POWER SUPPLY
INSTALL CRYOGENICS
INSTALL BOOM
ALIGNMENT
CLOSE OUT & SECURE
PH-2 PHYSICS & CHEMISTRY EXPERIMENT
INSTALLATION PREPARATIONS
INSTALL WIRE HARNESS
INSTALL MOUNTING PLATE
INSTALL SENSOR ASSEMBLY
CLOSE OUT & SECURE
PH-4 PHYSICS & CHEMISTRY EXPERIMENT
INSTALLATION PREPARATIONS
INSTALL WIRE HARNESS
INSTALL BOOM
INSTALL SUPPORT ELECTRONICS
INSTALL CANISTER
INSTALL MOLECULAR BEAM
INSTALL ION SOURCE
INSTALL SENSORS ON BOOM
CLOSE OUT & SECURE
PH-5 PHYSICS & CHEMISTRY EXPERIMENT
INSTALLATION PREPARATIONS
INSTALL WIRE HARNESS
INSTALL ION SOURCE/CHAMBER
INSTALL CHARGED PARTICLE DETECTOR
INSTALL CRYO SYSTEM
CLOSE OUT & SECURE
PAYLOAD 2 INSTALLATION
PALLET-MOUNTED HARDWARE



PAYLOAD 3 INSTALLATION FLOW

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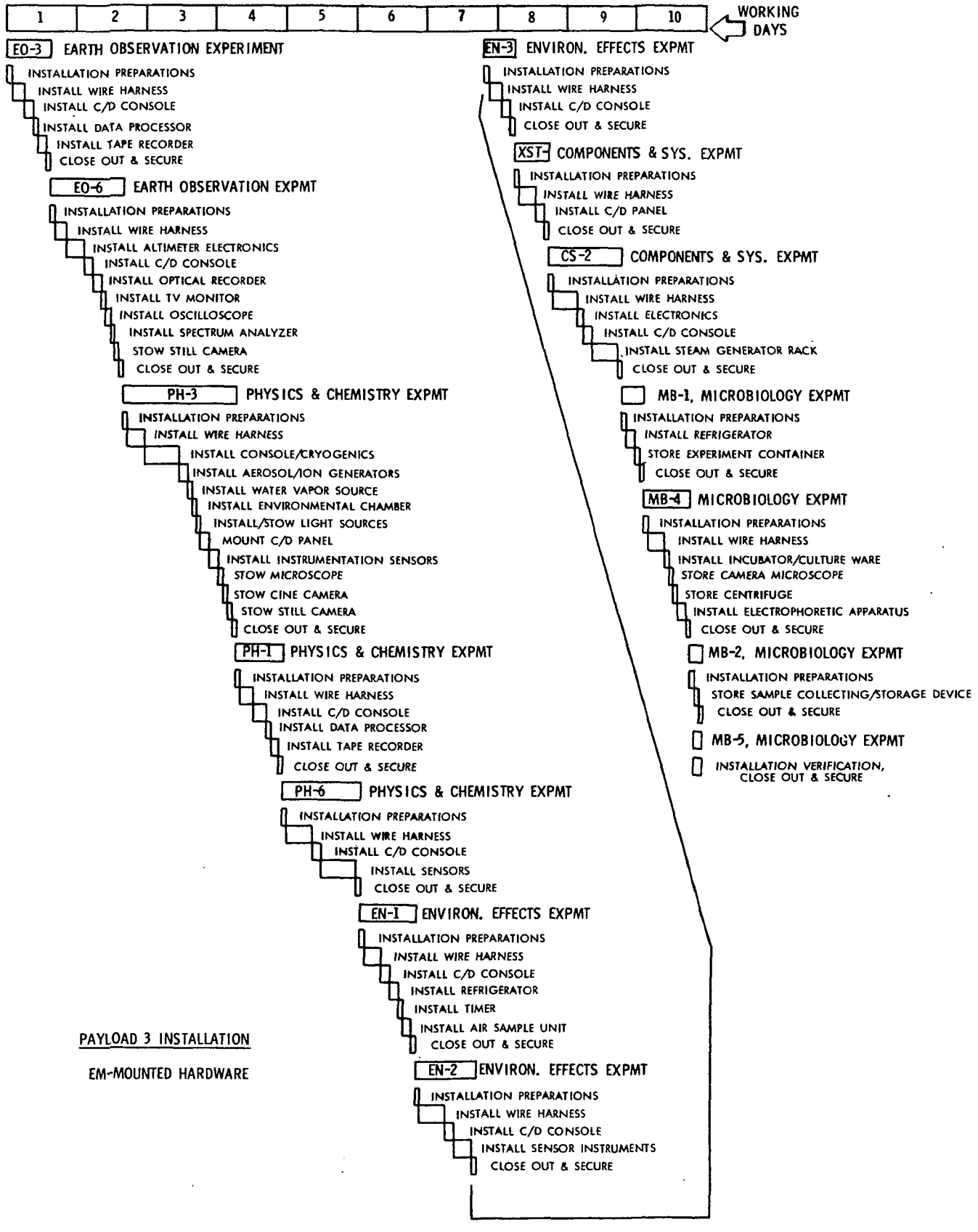
1
2
3
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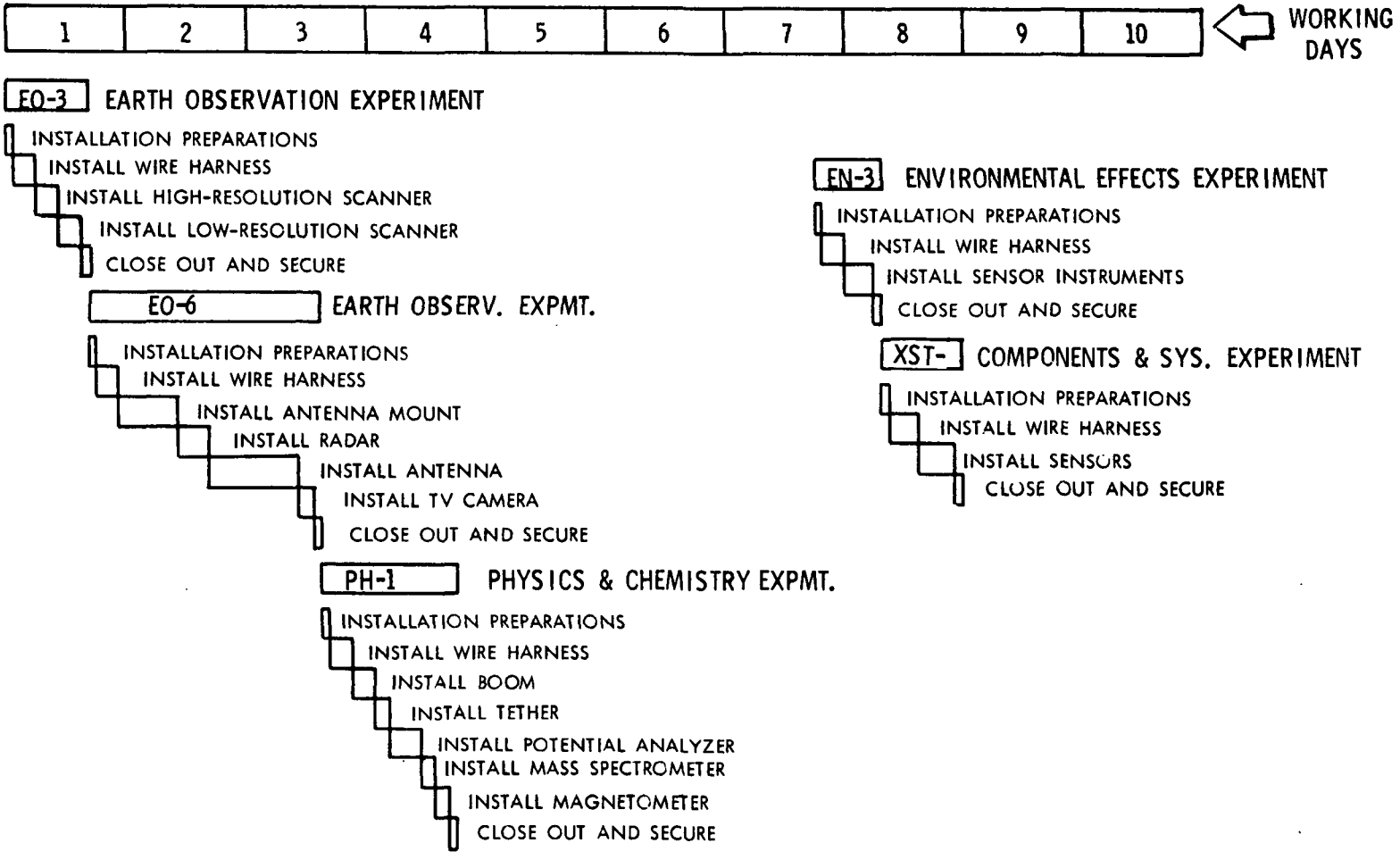
9
10
WORKING DAYS
EO-3 EARTH OBSERVATION EXPERIMENT
INSTALLATION PREPARATIONS
INSTALL WIRE HARNESS
INSTALL C/D CONSOLE
INSTALL DATA PROCESSOR
INSTALL TAPE RECORDER
CLOSE OUT & SECURE
EO-6 EARTH OBSERVATION EXPMT
INSTALLATION PREPARATIONS
INSTALL WIRE HARNESS
INSTALL ALTIMETER ELECTRONICS
INSTALL C/D CONSOLE
INSTALL OPTICAL RECORDER
INSTALL TV MONITOR
INSTALL OSCILLOSCOPE
INSTALL SPECTRUM ANALYZER
STOW STILL CAMERA
CLOSE OUT & SECURE
PH-3 PHYSICS & CHEMISTRY EXPMT
INSTALLATION PREPARATIONS
INSTALL WIRE HARNESS
INSTALL CONSOLE/CRYOGENICS
INSTALL AEROSOL/ION GENERATORS
INSTALL WATER VAPOR SOURCE
INSTALL ENVIRONMENTAL CHAMBER
INSTALL/STOW LIGHT SOURCES
MOUNT C/D PANEL
INSTALL INSTRUMENTATION SENSORS
STOW MICROSCOPE
STOW CINE CAMERA
STOW STILL CAMERA
CLOSE OUT & SECURE
PH-1 PHYSICS & CHEMISTRY EXPMT
INSTALLATION PREPARATIONS
INSTALL WIRE HARNESS
INSTALL C/D CONSOLE
INSTALL DATA PROCESSOR
INSTALL TAPE RECORDER
CLOSE OUT & SECURE
PH-6 PHYSICS & CHEMISTRY EXPMT
INSTALLATION PREPARATIONS
INSTALL WIRE HARNESS
INSTALL C/D CONSOLE
INSTALL SENSORS
CLOSE OUT & SECURE
EN-1 ENVIRON. EFFECTS EXPMT
INSTALLATION PREPARATIONS
INSTALL WIRE HARNESS
INSTALL C/D CONSOLE
INSTALL REFRIGERATOR
INSTALL TIMER
INSTALL AIR SAMPLE UNIT
CLOSE OUT & SECURE
EN-2 ENVIRON. EFFECTS EXPMT
INSTALLATION PREPARATIONS
INSTALL WIRE HARNESS
INSTALL C/D CONSOLE
INSTALL SENSOR INSTRUMENTS
CLOSE OUT & SECURE
EN-3 ENVIRON. EFFECTS EXPMT
INSTALLATION PREPARATIONS
INSTALL WIRE HARNESS
INSTALL C/D CONSOLE
CLOSE OUT & SECURE
XST COMPONENTS & SYS. EXPMT
INSTALLATION PREPARATIONS
INSTALL WIRE HARNESS
INSTALL C/D PANEL
CLOSE OUT & SECURE
CS-2 COMPONENTS & SYS. EXPMT
INSTALLATION PREPARATIONS
INSTALL WIRE HARNESS
INSTALL ELECTRONICS
INSTALL C/D CONSOLE
INSTALL STEAM GENERATOR RACK
CLOSE OUT & SECURE
MB-1, MICROBIOLOGY EXPMT
INSTALLATION PREPARATIONS
INSTALL REFRIGERATOR
STORE EXPERIMENT CONTAINER
CLOSE OUT & SECURE
MB-4 MICROBIOLOGY EXPMT
INSTALLATION PREPARATIONS
INSTALL WIRE HARNESS
INSTALL INCUBATOR/CULTURE WARE
STORE CAMERA MICROSCOPE
STORE CENTRIFUGE
INSTALL ELECTROPHORETIC APPARATUS
CLOSE OUT & SECURE
MB-2, MICROBIOLOGY EXPMT
INSTALLATION PREPARATIONS
STORE SAMPLE COLLECTING/STORAGE DEVICE
CLOSE OUT & SECURE
MB-5, MICROBIOLOGY EXPMT
INSTALLATION VERIFICATION, CLOSE OUT & SECURE
PAYLOAD 3 INSTALLATION
EM-MOUNTED HARDWARE



PAYLOAD 3 INSTALLATION

PALLET-MOUNTED HARDWARE

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APPENDIX B

B. EXPERIMENT CHECKOUT FLOW TIME ESTIMATES

APPENDIX B
EXPERIMENT CHECKOUT FLOW TIME ESTIMATES

Appendix B defines the general experiment checkout flow plus the checkout flow estimates for each individual experiment. Those estimates are based upon the following.

1. Initial alignment being performed as part of the installation of the experiment instruments.

2. The cameras containing test film.

3. The support equipment having previously been tested and verified.

The times are those required to perform a verification test of the instruments on an individual experiment basis. The tests are designed to verify the experiment/EM/pallet/igloo interfaces and to ensure that no damage has resulted due to the installation activity. The general checkout procedure is as follows.

1. Set up experiment equipment and activate support equipment.

2. Activate control and display consoles.

3. Check out control and display console concurrent with instrument checkout.

4. Verify operation of moving parts of pallet-installed equipment.

5. Verify operation of moving parts of experiment module installed equipment.

6. Verify operation of instruments on the pallet.

7. Verify operation of instruments in the EM/canister.

8. Check out miscellaneous equipment.

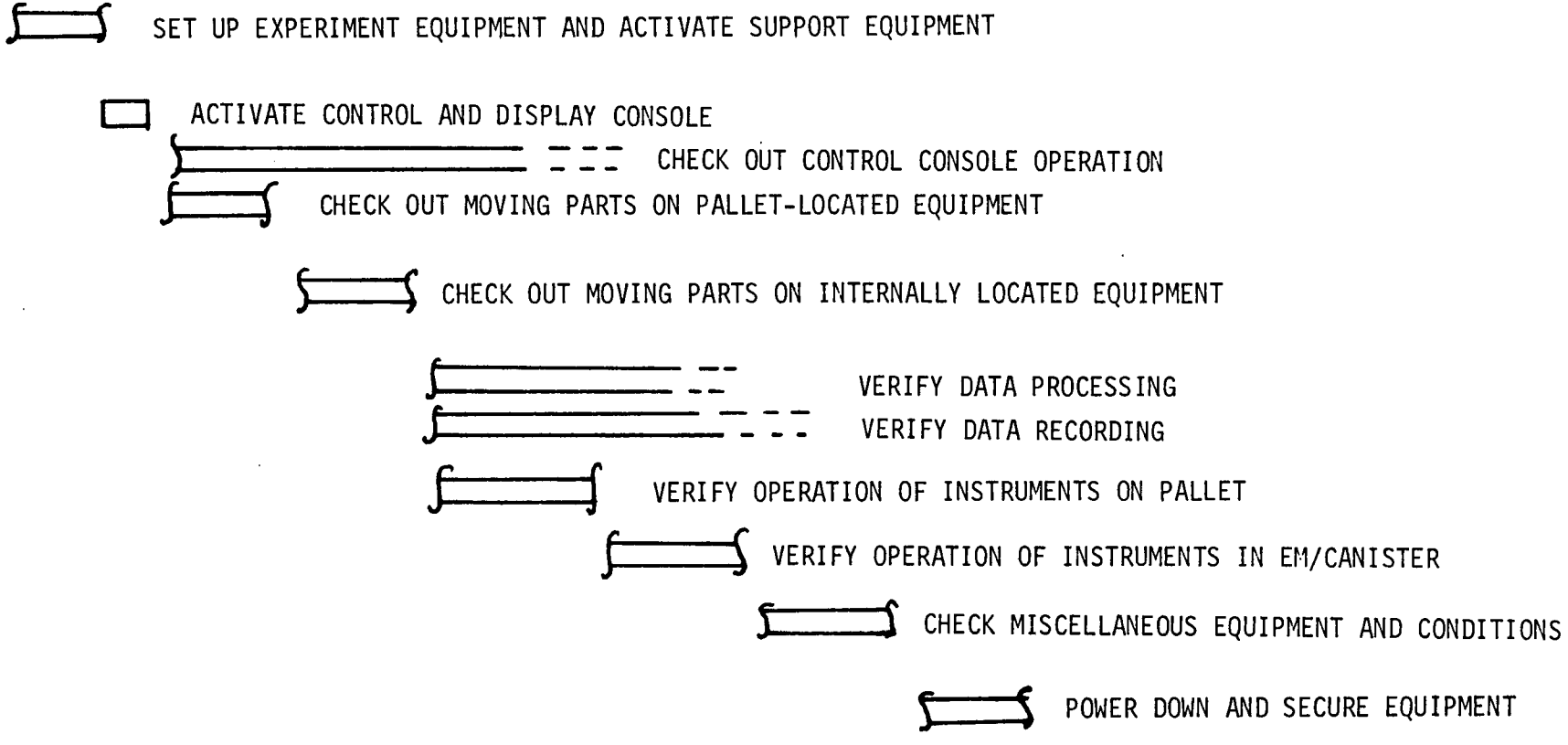
9. Verify data processing/recording concurrent with checkout of the instruments.

10. Power down and secure the equipment.

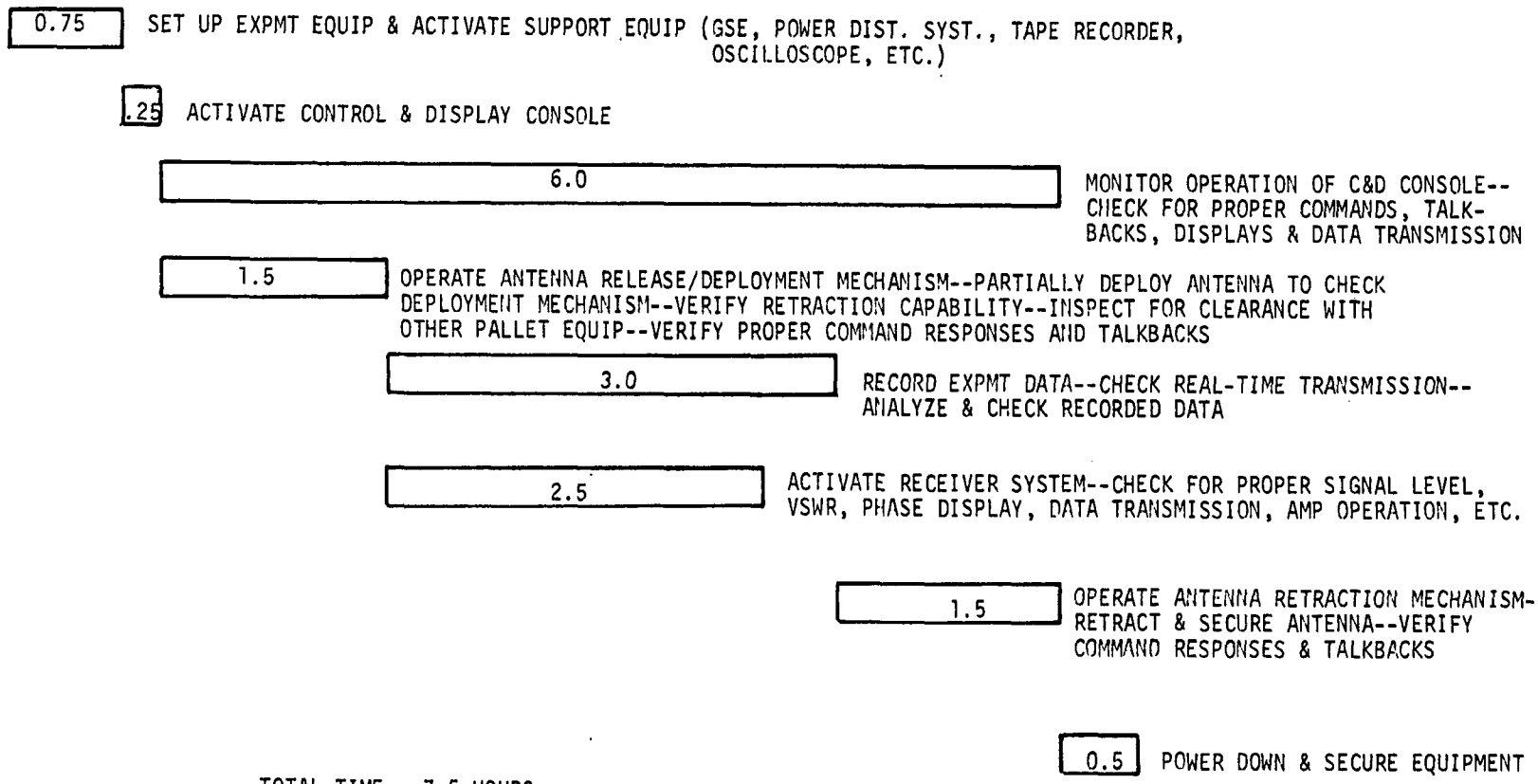
The checkout flow details for each individual experiment are contained on the flow charts for the respective experiment. The times for all of the ATL experiments are summarized in Table B-1.

Table B-1. Summary of ATL Experiment Checkout Tasks

Discipline/Experiment		Checkout Time (hours)
NAVIGATION		
NV-1	Microwave Interferometer	7.5
NV-2	Autonomous Navigation	9.5
NV-3	Multipath Measurements	4.25
EARTH OBSERVATIONS		
EO-1	Lidar Measurements	5.25
EO-2	Tunable Lasers	5.5
EO-3	Multispectral Scanner	3.75
EO-4	Radiometer	6.0
EO-5	Laser Ranging	5.5
EO-6	Microwave Altimetry	7.25
EO-7	Search and Rescue Aids	7.75
EO-8	Imaging Radar	7.25
EO-9	RF Noise	6.5
PHYSICS AND CHEMISTRY		
PH-1	Wake Dynamics	5.25
PH-2	Barium Cloud Release	9.25
PH-3	Aerosol Properties	7.25
PH-4	Neutral Gas Parameters	6.75
PH-5	Radiation Environment	6.25
PH-6	Meteor Spectroscopy	5.75
MICROBIOLOGY		
MB-1	Colony Growth	4.75
MB-2	Micro-Organism Transfer	3.0
MB-3	Biological Cell Electrical Field Opacity	4.0
MB-4	Bio Cell Electrical Characteristics	4.25
MB-5	Bio Cell Properties	3.0
ENVIRONMENTAL EFFECTS		
EN-1	Micro-Organism Sampling	2.0
EN-2	Material Fatigue	4.5
EN-3	Non-Metallic Materials Degradation	3.75
COMPONENTS AND SYSTEMS		
CS-2	Zero-Gravity Steam Generator	4.0
XST-	Contamination Monitor	2.5



GENERAL CHECKOUT PROCEDURE



NV-1 MICROWAVE INTERFEROMETER

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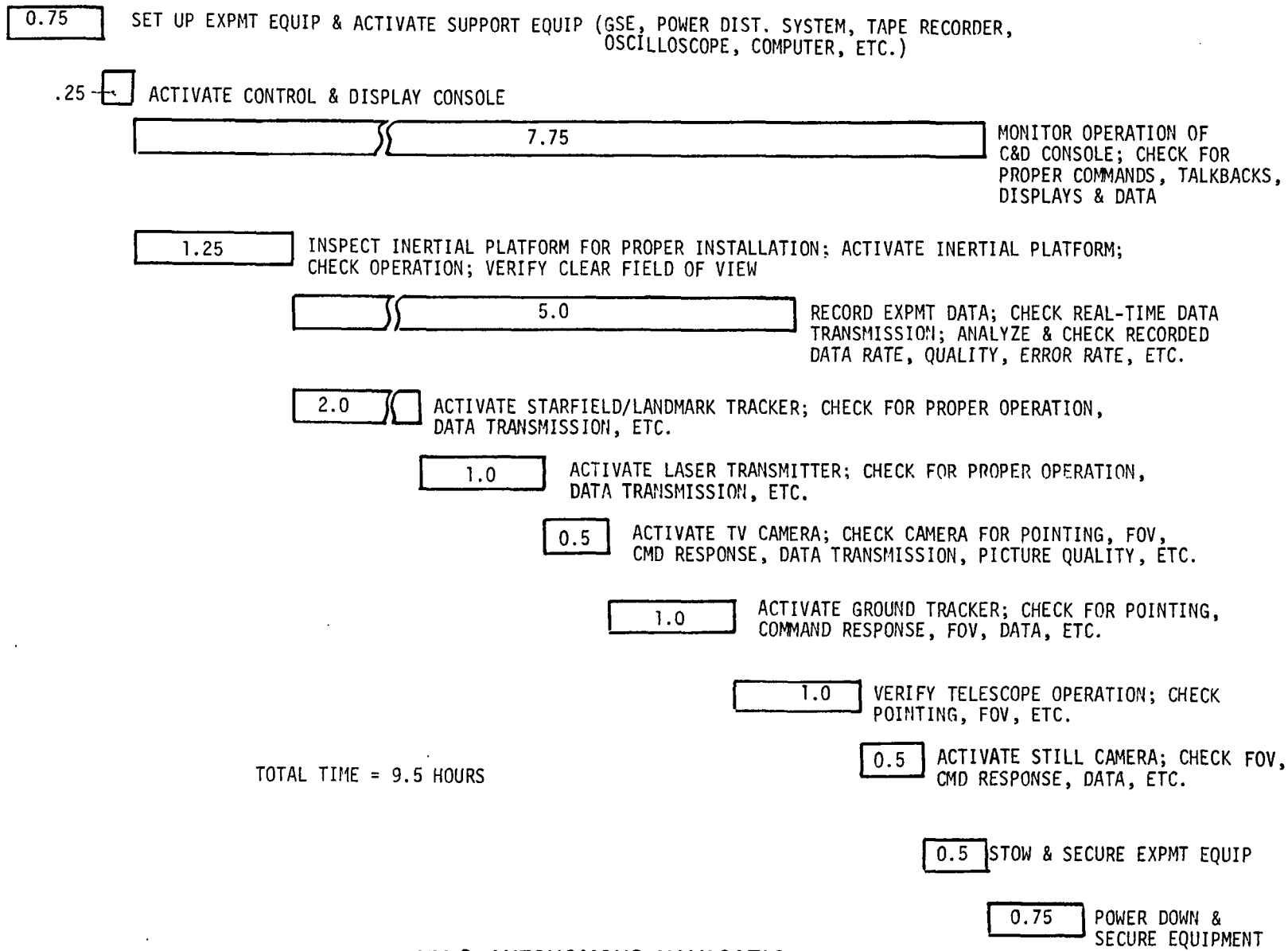
Rockwell International



NV-2 AUTONOMOUS NAVIGATION

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0.75 SET UP EXPMT EQUIP & ACTIVATE SUPPORT EQUIP (GSE, PWR DIST SYS, TAPE RECORDERS, ETC.)

0.25 ACTIVATE CONTROL & DISPLAY CONSOLE

2.75 MONITOR OPERATION OF C&D CONSOLE; CHECK FOR PROPER COMMANDS, TALKBACKS, DISPLAYS, DATA TRANSMISSION, ETC.

1.0 DEPLOY ANTENNA; CHECK FOR PROPER DEPLOYMENT, ADEQUATE CLEARANCE, ANTENNA POINTING, SCAN ANGLE & RATE, TALKBACK, ETC.

0.75 ACTIVATE RECEIVER/ANTENNA SYSTEM; CHECK POWER,SIGNAL LEVEL, VSWR, DATA TRANSMISSION, DISPLAYS, ETC.

1.25 RECORD EXPMT DATA; CHECK REAL-TIME DATA TRANSMISSION; ANALYZE AND CHECK RECORDED DATA

0.5 RETRACT & SECURE ANTENNA; CHECK FOR PROPER RETRACTION, COMMAND RESPONSE, TALKBACKS, ETC.

0.5 POWER DOWN AND SECURE EQUIPMENT

TOTAL TIME = 4.25 HOURS

NV-3 MULTIPATH MEASUREMENTS

0.5 SET UP EXPMT EQUIP & ACTIVATE SUPPORT EQUIP (GSE, POWER DIST SYS, TAPE RECORDER, OSCILLOSCOPE, COMPUTER, ETC.)

.25 ACTIVATE C&D CONSOLE

4.0 MONITOR OPERATION OF CONTROL & DISPLAY CONSOLE; CHECK FOR PROPER COMMANDS, TALKBACKS, DISPLAYS, DATA PROCESSING, ETC.

1.0 OPERATE BOOM RELEASE/DEPLOYMENT MECHANISM; PARTIALLY DEPLOY; CHECK FOR CLEARANCE, COMMAND RESPONSE, TALKBACKS, DISPLAYS, RETRACTION CAPABILITY, ETC.

1.0 ACTIVATE LIDAR TRANSMITTER; CHECK LASER PULSE OUTPUT, COMMAND RESPONSE, DATA TRANSMISSION, DISPLAYS, ETC.

1.5 RECORD EXPMT DATA; CHECK REAL-TIME DATA TRANSMISSION; ANALYZE AND CHECK RECORDED DATA

0.5 ACTIVATE CINE CAMERA; CHECK CMD RESPONSE, FILM ADVANCE, ETC.

0.5 RETRACT & SECURE BOOM; CHECK FOR PROPER RETRACTION, COMMAND RESPONSE, TALKBACKS, RETRACTION TIME, ETC.

0.5 POWER DOWN AND SECURE EQUIPMENT

TOTAL TIME = 5.25 HOURS

EO-1 LIDAR MEASUREMENTS

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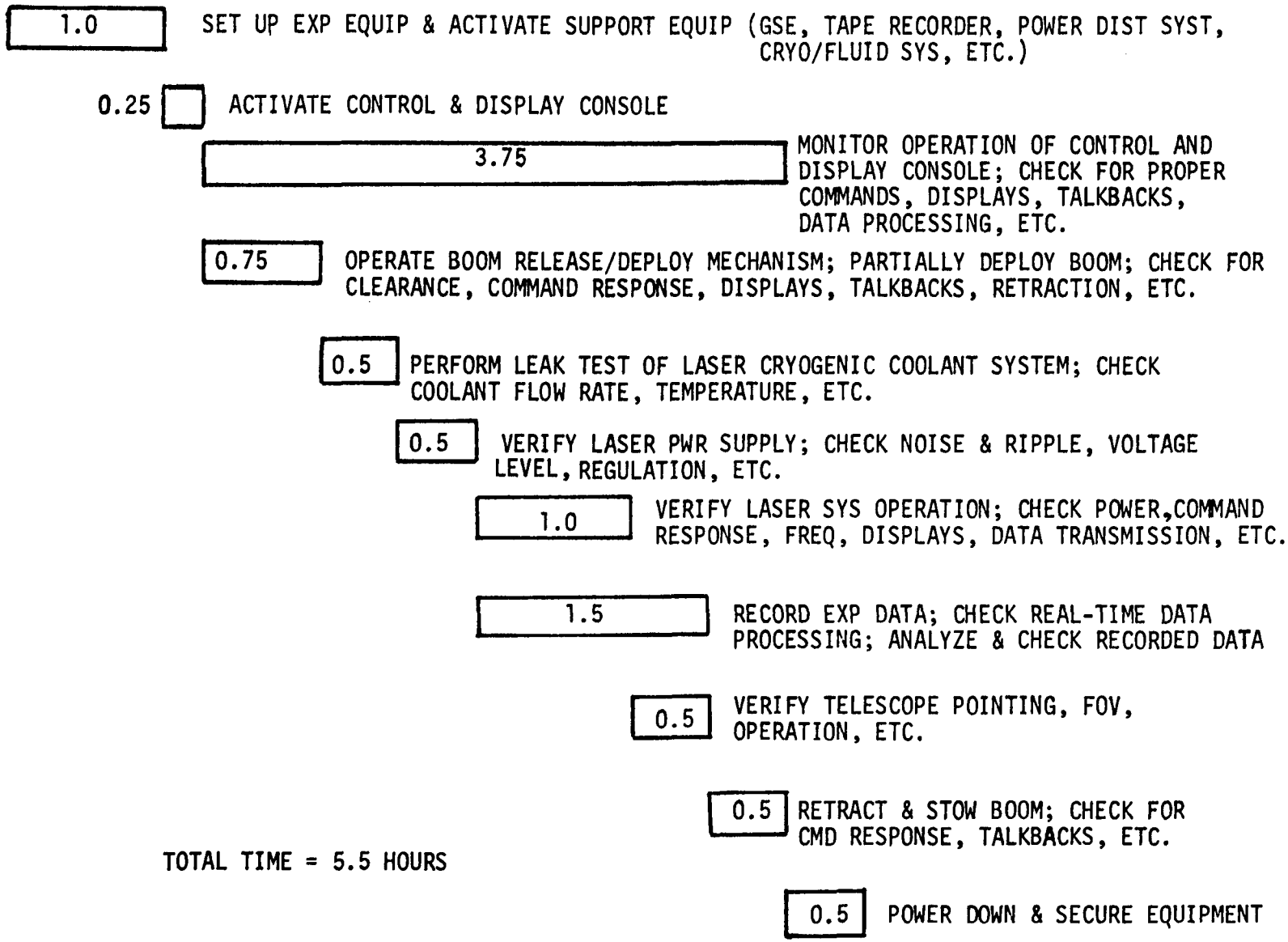

EO-2 TUNABLE LASERS

Space Division
Rockwell International

0.5 SET UP EXP EQUIP & ACTIVATE SUPPORT EQUIP (GSE, POWER DIST SYS, TAPE RECORDER, ETC.)

0.25 ACTIVATE CONTROL & DISPLAY CONSOLE

2.5 MONITOR OPERATION OF C&D CONSOLE OPERATION; CHECK FOR PROPER COMMANDS, DISPLAYS, TALKBACKS, DATA PROCESSING, ETC.

1.0 ACTIVATE HIGH-RESOLUTION SCANNER SYS; CHECK CMD RESPONSE, DISPLAYS, DATA SIGNALS & TRANSMISSION FOR AMBIENT ENVIRONMENT, POINTING, FOV, ETC.

1.0 ACTIVATE LOW-RESOLUTION SCANNER SYS; CHECK CMD RESPONSE, DISPLAYS, DATA SIGNALS & TRANSMISSION FOR AMBIENT ENVIRONMENT, POINTING, FOV, ETC.

2.5 RECORD EXP DATA; CHECK REAL TIME AND RECORDED DATA FOR PROPER PROCESSING, DATA RATE, QUALITY, ACCURACY, BIT ERROR, NOISE LEVEL, ETC.

0.5 POWER DOWN AND SECURE EQUIPMENT

TOTAL TIME = 3.75 HOURS

EO-3 MULTISPECTRAL SCANNER

Space Division
Rockwell International

0.75 SET UP EXP EQUIP & ACTIVATE SUPPORT EQUIP (GSE, POWER DIST SYS, TAPE RECORDER, OSCILLOSCOPE, SPECTRUM ANALYZER, SIG GEN, ETC.)

0.25 ACTIVATE CONTROL & DISPLAY CONSOLE

4.5 MONITOR OPERATION OF C&D CONSOLE; CHECK FOR PROPER COMMANDS, DISPLAYS, TALKBACKS, DATA PROCESSING, ETC.

1.0 OPERATE ANTENNA RELEASE/DEPLOYMENT MECHANISM; DEPLOY ANTENNA AND CHECK FOR CLEARANCE, FOV, COMMAND RESPONSE, DISPLAYS, TALKBACKS, ETC.

1.0 ACTIVATE RADIOMETER SYSTEM; CHECK COMMAND RESPONSE, DATA PROCESSING, RCVR SIG LEVEL & OPERATION, DISPLAYS, ELECTRONICS OPERATION, ETC.

1.0 CHECK RADIOMETER FOR PROPER DATA TRANSMISSION FOR AMBIENT ENVIRONMENT; CHECK CMD RESPONSE, ETC.

1.5 RECORD EXP DATA; CHECK REAL-TIME AND RECORDED DATA FOR PROPER PROCESSING, DATA FREQ., NOISE LEVEL, ACCURACY, ETC.

0.5 ACTIVATE STILL CAMERA; CHECK FOV, CMD RESPONSE, DATA, ETC.

0.5 RETRACT & STOW ANTENNA; CHECK FOR CMD RESPONSE, TASLKBACKS, ETC.

TOTAL TIME = 6.0 HOURS

0.5 POWER DOWN AND SECURE EQUIPMENT

EO-4 RADIOMETER

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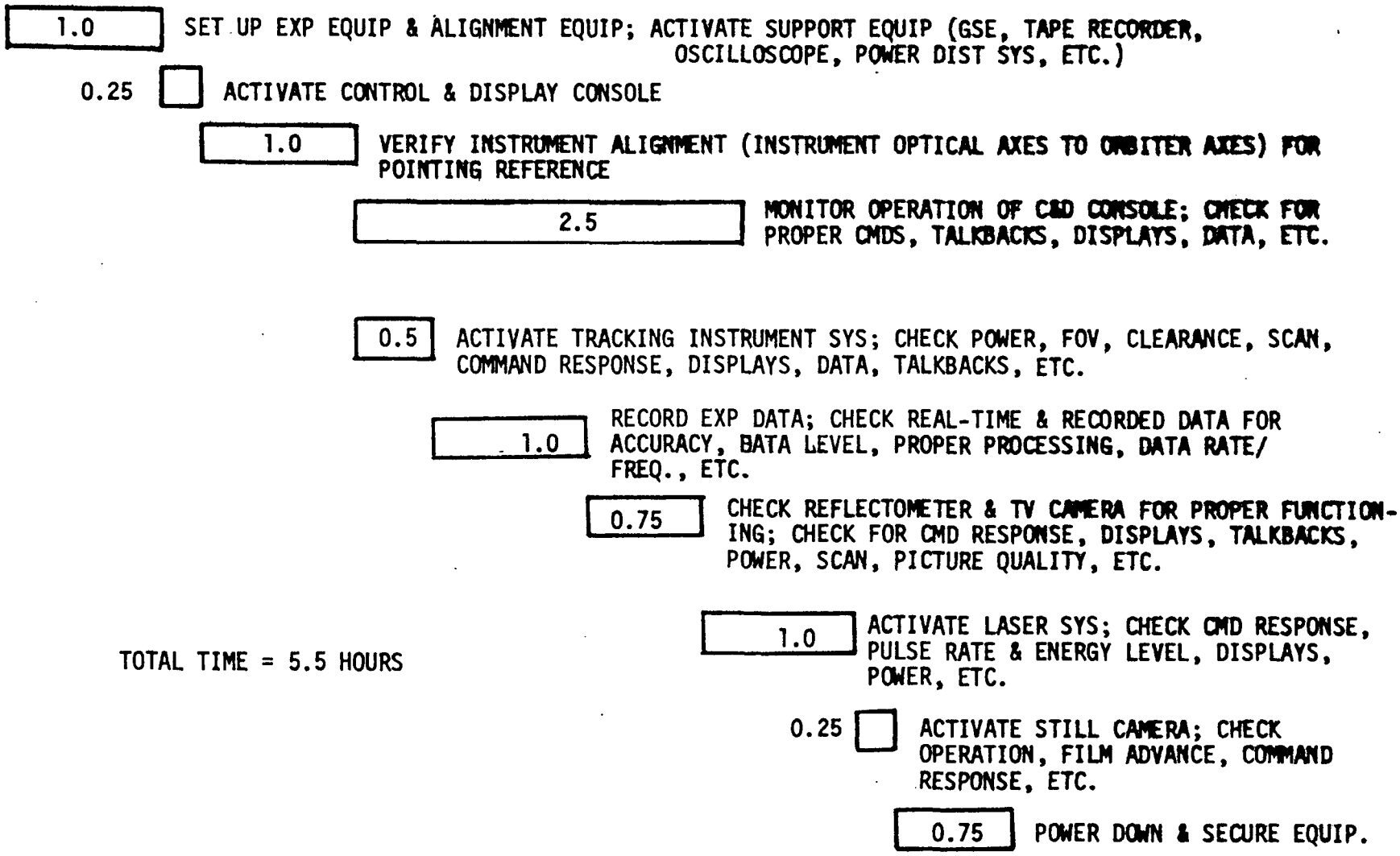
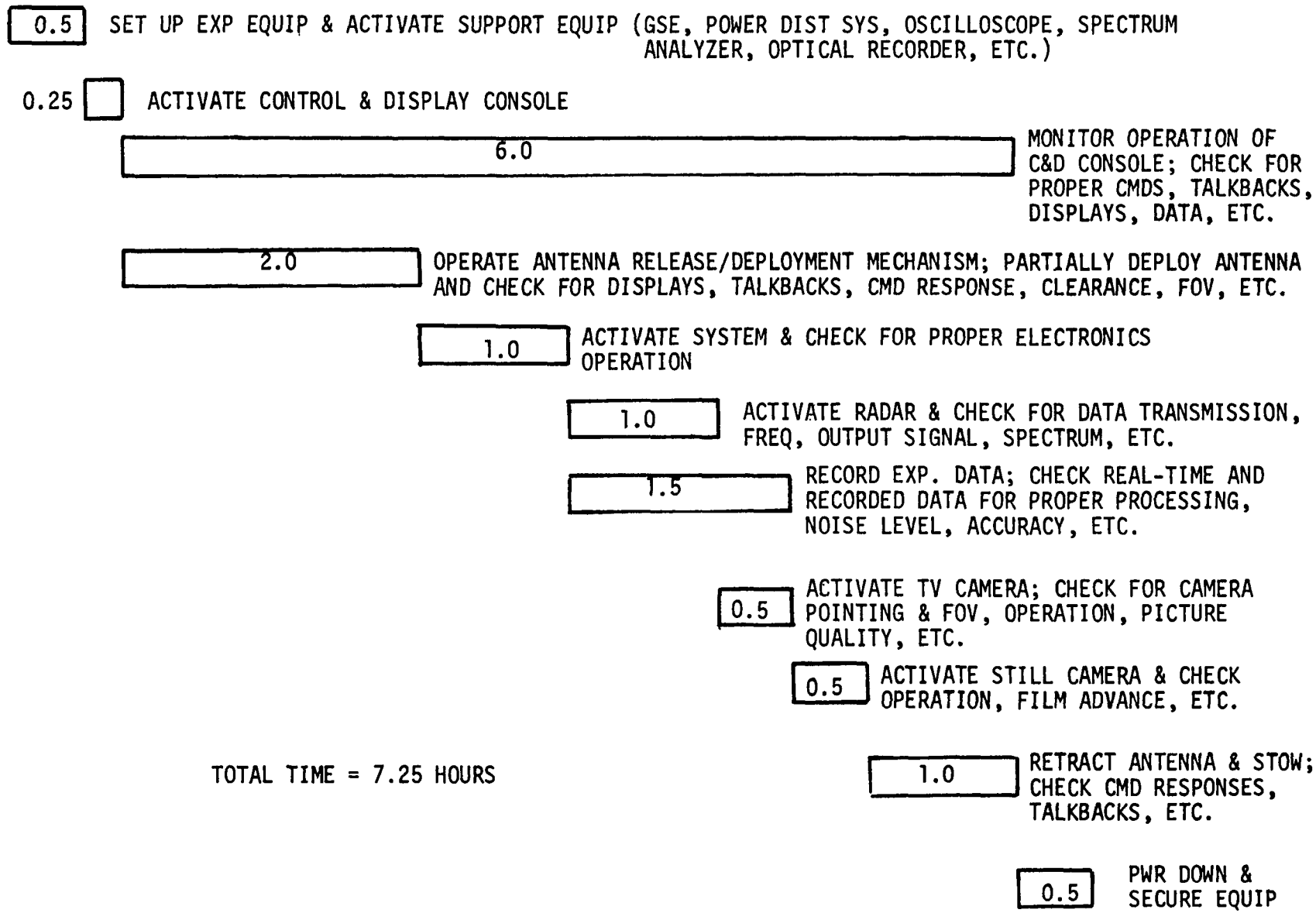
Rockwell International



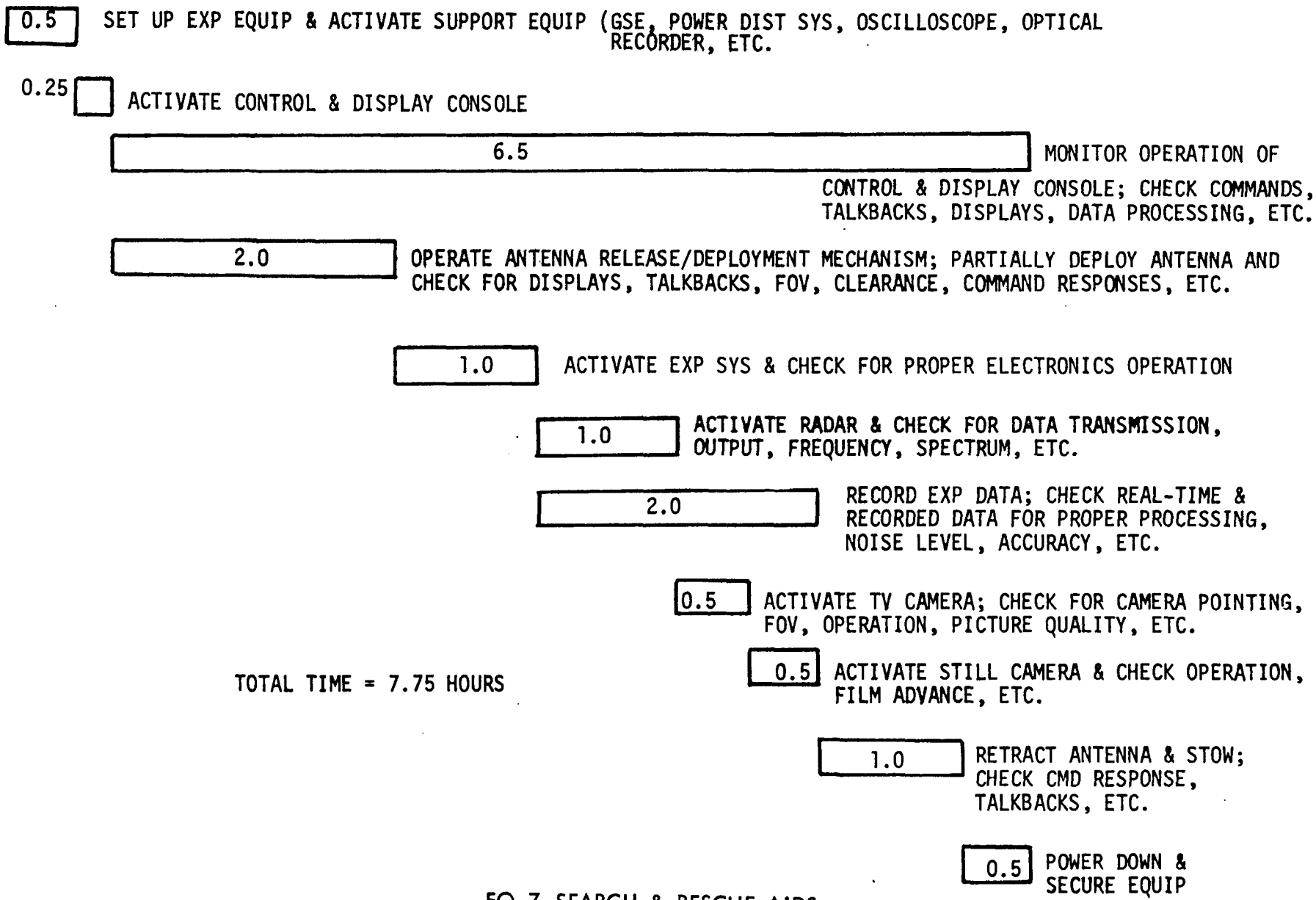
EO-5 LASER RANGING

Space Division
Rockwell International

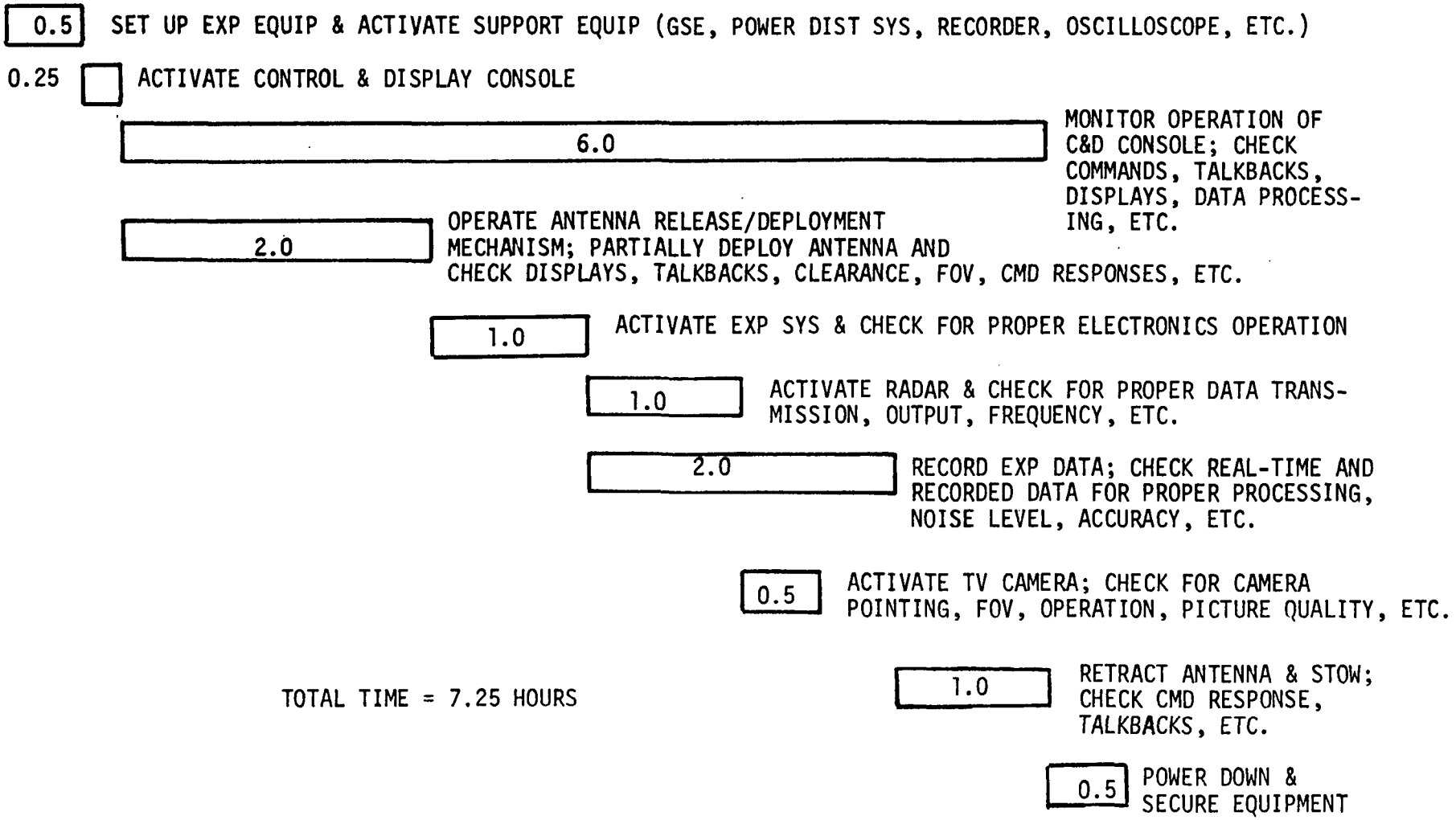


EO-6 MICROWAVE ALTIMETRY

Space Division
Rockwell International

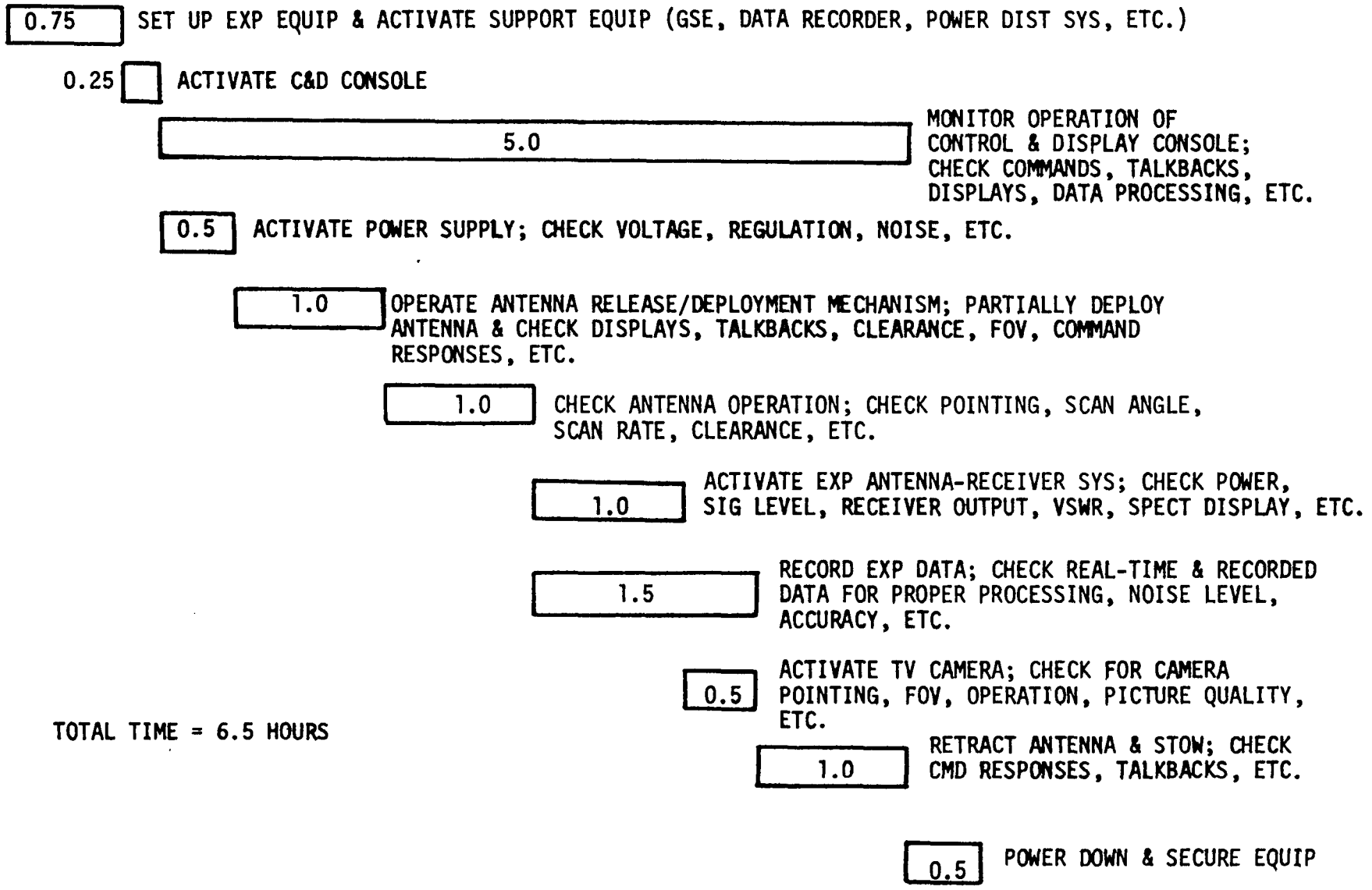


EO-7 SEARCH & RESCUE AIDS



EO-8 IMAGING RADAR

Space Division
Rockwell International



EO-9 RF NOISE MEASUREMENT

0.5 ACTIVATE GSE & SUPPORT EQUIP (POWER, LIGHTING, TEST EQUIP, DATA PROCESSING EQUIP, TAPE RECORDERS, COMPUTER, EPHEMERIS DATA LINK, ETC.)

0.25 ACTIVATE CONTROL & DISPLAY CONSOLE AND EXPERIMENT COMPONENTS

3.5 MONITOR OPERATION OF C&D CONSOLE, DATA PROCESSOR & DATA RECORDER & EPHEMERIS DATA LINK; CHECK FOR PROPER SENDING & RECEIVING OF SIGNALS TO/FROM SENSORS; CHECK COORDINATION OF SENSOR DATA WITH EPHEMERIS DATA.

0.5 OPERATE BOOM RELEASE MECH (FWD & AFT); PARTIALLY DEPLOY EA BOOM TO CHECK BOOM DEPLOYMENT MECH; OPERATE BOOM ROTATION DEVICES; INSPECT FOR CLEARANCE BETWEEN DEPLOYED BOOM & ALL OTHER EQUIPMENT ON PALLET.

1.0 ACTIVATE POTENTIAL ANALYZER; CHECK FOR PROPER DATA TRANSMISSION CORRESPONDING TO SENSING OF AMBIENT ENVIRONMENT.

0.5 ACTIVATE MASS SPECTROMETERS; CHECK FOR PROPER DATA TRANSMISSION FOR AMBIENT ENVIRONMENT AND REFERENCE STANDARD SAMPLES.

0.5 ACTIVATE FLUXGATE MAGNETOMETERS; CHECK FOR PROPER DATA TRANSMISSION CORRESPONDING TO SENSING OF AMBIENT ENVIRONMENT.

1.0 ACTIVATE ELECTROSTATIC PROBES; CHECK FOR PROPER DATA TRANSMISSION FOR SENSING AMBIENT ENVIRONMENT.

0.5 ANALYZE & CHECK REAL-TIME DATA PROCESSING OF SENSOR SIGNALS BY DATA PROCESSOR & ON-BOARD COMPUTER.

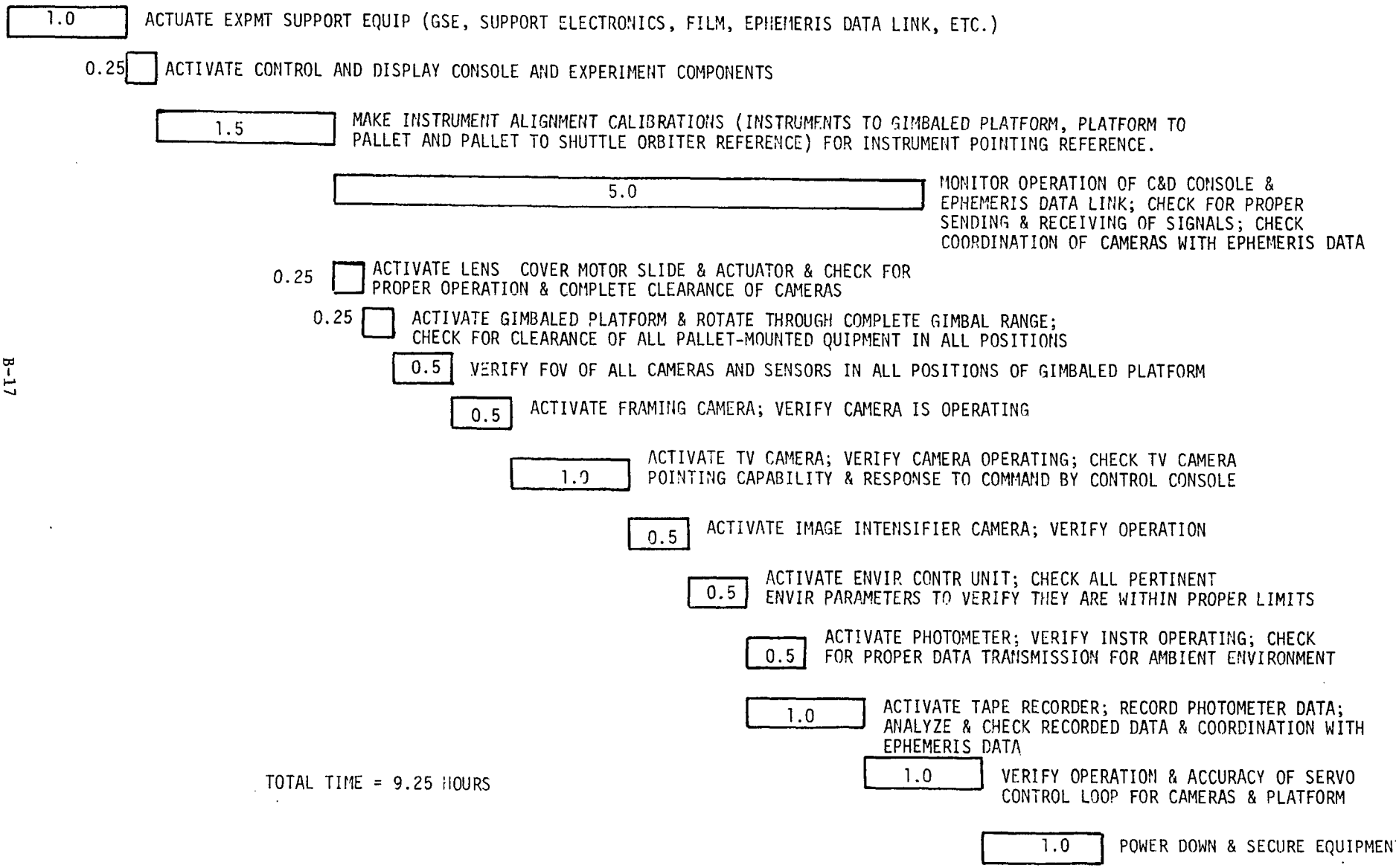
0.5 ANALYZE & CHECK DATA FROM TAPE RECORDER; CHECK FOR CORRECT RECORDING RATE & CAPACITY.

TOTAL TIME = 5.25 HOURS

0.5 POWER DOWN & SECURE EQUIPMENT

PH-1 SPACECRAFT WAKE DYNAMICS

Space Division
Rockwell International



PH-2 BARIUM CLOUD RELEASE

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Rockwell International

0.5 ACTIVATE EXPMT SUPPORT EQUIP (GSE, SUPPORT ELECTRONICS, TAPE RECORDER, ETC.)

0.25 ACTIVATE CONTROL & DISPLAY CONSOLE AND EXPERIMENT COMPONENTS

3.0 PERFORM LEAK TESTS ON GAS SOURCE TANKS AND AEROSOL ION & WATER VAPOR GENERATORS AND ALL GAS LINES AND FITTINGS

3.0 MONITOR OPERATION OF CONTROL CONSOLE; CHECK FOR PROPER SENDING & RECEIVING OF SIGNALS TO AND FROM THE EXPERIMENT COMPONENTS AND SENSORS

0.25 ACTIVATE LIGHT SOURCE & MICROSCOPE; VERIFY THAT BOTH ARE OPERATIONAL; CHECK MICROSCOPE OPERATION WITH REFERENCE STANDARD SAMPLES

0.25 ACTIVATE STILL CAMERA AND VERIFY CAMERA IS OPERATING

0.5 ACTIVATE CINE CAMERA AND VERIFY CAMERA IS OPERATING

1.5 ACTIVATE ENVIR CHAMBER; CHECK THAT ALL PERTINENT ENVIR PARAMETERS ARE CORRECT & RESPOND RAPIDLY & ACCURATELY WHEN COMMANDED

1.5 ACTIVATE INSTR SENSORS (PRESS, TEMP & HUMIDITY); CHECK THAT SENSOR READINGS CORRESPOND WITHIN TOLERANCES TO CHAMBER ENVIR.

2.0 ANALYZE & CHECK DATA RECORDING OF SENSOR DATA; VERIFY CORRECT DATA RECORDING RATE AND CAPACITY

TOTAL HOURS = 7.25

0.5 ACTIVATE AEROSOL GEN; CHECK CORRECT RATE OF GENERATION & FLOW OF AEROSOLS TO ENVIRONMENTAL CHAMBER

0.5 ACTIVATE ION GEN; CHECK FOR CORRECT RATE & ENERGY OF IONS GENERATED; CHECK CORRECT FLOWRATE OF IONS TO ENVIR CHAMBER

0.5 ACTIVATE WATER VAPOR SOURCE; CHECK FOR CORRECT FLOWRATE & TEMP OF WATER VAPOR ENTERING ENVIRONMENTAL CHAMBER

0.5 POWER DOWN & SECURE EQUIPMENT

PH-3 OPTICAL PROPERTIES OF AEROSOLS

0.5 ACTIVATE SUPPORT EQUIPMENT (GSE, SUPPORT ELECTRONICS, DATA PROCESSING EQUIPMENT, TAPE RECORDERS, COMPUTER, ETC.)

0.25 ACTIVATE CONTROL & DISPLAY CONSOLE AND EXPERIMENT COMPONENTS

0.5 OPERATE INSTRUMENT CANISTER RELEASE MECH; PARTIALLY DEPLOY INSTRUMENT BOOM; INSPECT FOR CLEARANCE BETWEEN DEPLOYED BOOM, CANISTER COVER & OTHER PALLET-MOUNTED EQUIPMENT

3.5 MONITOR OPERATION OF C&D CONSOLE, OSCILLOSCOPE, AND DATA RECORDERS; CHECK FOR PROPER SENDING & RECEIVING OF SIGNALS TO AND FROM SENSORS

0.25 ACTIVATE ION SOURCE & TEST FOR PROPER RATE & ENERGY OF ION RELEASE

0.25 ACTIVATE ION COUNTING COLLECTOR SYSTEM; CHECK FOR PROPER DATA TRANSMISSION FOR AMBIENT ENVIRONMENT

0.25 ACTIVATE MASS FILTER & ION DETECTOR; CHECK FOR PROPER DATA TRANSMISSION FOR AMBIENT ENVIRONMENT

0.25 ACTIVATE MOLECULAR BEAM SUBDIVIDER; VERIFY INSTRUMENT IS OPERATING

1.5 ACTIVATE MOLECULAR BEAM MASS SPECTROMETER; CHECK FOR PROPER DATA TRANSMISSION FOR AMBIENT ENVIRONMENT & REFERENCE STANDARD SAMPLES

2.5 ANALYZE & CHECK REAL-TIME DATA PROCESSING OF SENSOR SIGNALS BY ON-BOARD COMPUTER

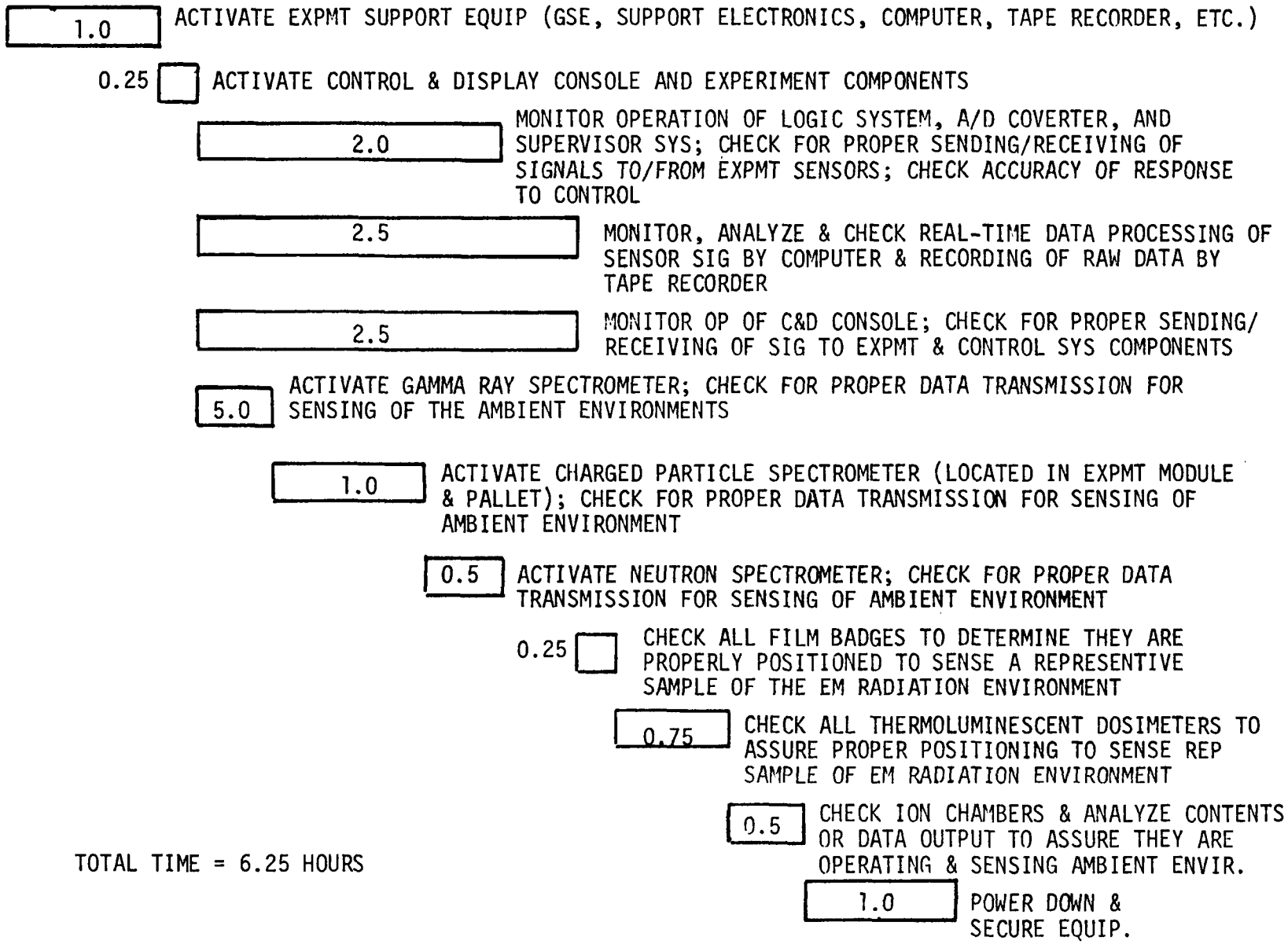
2.5 ANALYZE PROCESSED DATA FROM TAPE RECORDER; CHECK FOR CORRECT RECORDING RATES & CAPACITY

1.0 VERIFY VACUUM INTEGRITY OF INSTRUMENT CANISTER

TOTAL TIME = 6.75 HOURS

1.0 POWER DOWN AND SECURE EQUIPMENT

PH-4 MAPPING UPPER ATMOSPHERIC NEUTRAL GAS PARAMETERS



PH-5 SPACECRAFT RADIATION ENVIRONMENT

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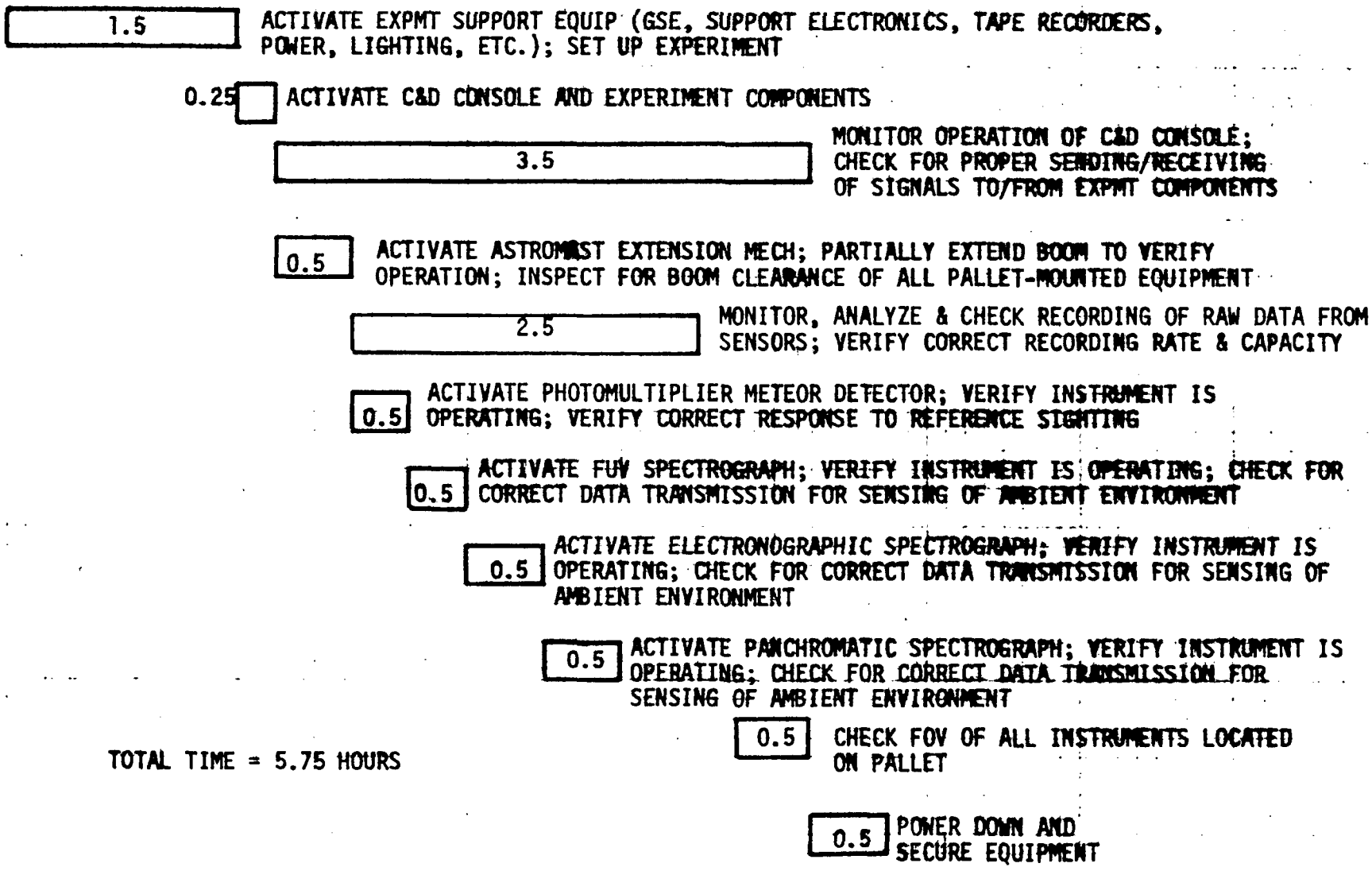


PH-6 ULTRAVIOLET METEOR SPECTROSCOPY FROM NEAR-EARTH ORBIT

0.75 SET UP EQUIP & ACTIVATE SUPPORT EQUIP (GSE, POWER DIST SYS, TAPE RECORDER, C&W SYS, ETC.)

0.25 ACTIVATE CONTROL & DISPLAY CONSOLE

2.5 MONITOR OPERATION OF C&D CONSOLE; CHECK FOR COMMANDS, TALKBACKS, DISPLAYS & RECEIPT OF EXPERIMENT DATA

2.5 ACTIVATE CAMERA/LIGHT SOURCE; CHECK FOR PROPER CAMERA OPERATION, SEQUENCING, TIMING & FILM ADVANCE; VERIFY PROPER LIGHT SEQUENCING

1.0 ACTIVATE INCUBATOR; CHECK FOR PROPER POWER, TEMP, DISPLAYS, ETC. VERIFY PERTINENT ENVIRONMENTAL PARAMETERS WITHIN PROPER LIMITS

1.0 ACTIVATE REFRIGERATOR; CHECK FOR PROPER POWER, TEMP, DISPLAYS, ETC. VERIFY PERTINENT ENVIRONMENTAL PARAMETERS WITHIN PROPER LIMITS

3.0 RECORD EXP DATA; CHECK REAL-TIME DATA PROCESSING; ANALYZE AND CHECK RECORDED DATA

POWER DOWN & SECURE EQUIPMENT

TOTAL TIME = 4.75 HOURS

MB-1 COLONY GROWTH

Space Division
Rockwell International

0.75 SET UP EXP EQUIP & ACTIVATE SUPPORT EQUIP (GSE, POWER DIST SYS, TAPE RECORDER, C&W SYS, ETC.)

0.25 ACTIVATE CONTROL AND DISPLAY CONSOLE

1.5 MONITOR OPERATION OF C&D CONSOLE; CHECK FOR COMMANDS, TALKBACKS, DISPLAYS AND RECEIPT OF EXPERIMENT DATA

1.0 ACTIVATE INCUBATOR; CHECK FOR PROPER POWER, TEMP, DISPLAYS, ETC. VERIFY PERTINENT ENVIRONMENTAL PARAMETERS WITHIN PROPER LIMITS

1.0 ACTIVATE REFRIGERATOR; CHECK FOR PROPER POWER, TEMP, DISPLAYS, ETC. VERIFY PERTINENT ENVIRONMENTAL PARAMETERS WITHIN PROPER LIMITS

1.5 RECORD EXPERIMENT DATA; CHECK REAL-TIME DATA PROCESSING; ANALYZE AND CHECK RECORDED DATA

0.5 POWER DOWN & SECURE EQUIPMENT

TOTAL TIME = 3.0 HOURS

MB-2 MICRO-ORGANISM TRANSFER

Space Division
Rockwell International

0.75 SET UP EXP EQUIP & ACTIVATE SUPPORT EQUIP (GSE, POWER DIST SYS, C&W SYS, TAPE RECORDER, ETC.)

0.25 ACTIVATE CONTROL & DISPLAY CONSOLE

2.5 MONITOR OPERATION OF C&D CONSOLE; CHECK FOR COMMANDS, TALKBACKS, DISPLAYS, AND RECEIPT OF EXPERIMENT DATA

1.0 ACTIVATE REFRIGERATOR; CHECK FOR PROPER POWER, TEMP, DISPLAYS, ETC. VERIFY PERTINENT ENVIRONMENTAL PARAMETERS WITHIN PROPER LIMITS

1.0 ACTIVATE INCUBATOR; CHECK FOR PROPER POWER, TEMP, DISPLAYS, ETC. VERIFY PERTINENT ENVIRONMENTAL PARAMETERS WITHIN PROPER LIMITS

2.0 ACTIVATE ELECTRONIC SENSOR, VOLUME SPEC, & COULTER COUNTER; INSTALL TEST SPECIMEN & CHECK FOR PROPER POWER, COMMAND RESPONSE, DISPLAYS & DATA PROCESSING

2.5 RECORD EXP DATA; CHECK REAL-TIME DATA PROCESSING; ANALYZE & VERIFY RECORDED DATA

0.5 ACTIVATE CAMERA/MICROSCOPE; CHECK CAMERA OPERATION/ SEQUENCING; CHECK MICROSCOPE OPERATIONS; VERIFY FILM ADVANCE

0.5 POWER DOWN & SECURE EQUIPMENT

TOTAL TIME = 4.0 HOURS

MB-3 BIOLOGICAL CELLS

Space Division
Rockwell International

0.75 SET UP EXP EQUIP & ACTIVATE SUPPORT EQUIP (GSE, POWER DIST SYS, TAPE RECORDER, C&W SYS, ETC.)

0.25 ACTIVATE CONTROL & DISPLAY CONSOLE

2.5 MONITOR OPERATION OF C&D CONSOLE; CHECK FOR PROPER COMMANDS, TALKBACKS, DISPLAYS, & EXPERIMENT DATA PROCESSING

1.0 ACTIVATE INCUBATOR; CHECK FOR PROPER POWER, TEMP, DISPLAYS, ETC. VERIFY PERTINENT ENVIRONMENTAL PARAMETERS WITHIN LIMITS

1.0 ACTIVATE REFRIGERATOR; CHECK FOR PROPER POWER, TEMP, DISPLAYS, ETC. VERIFY PERTINENT ENVIRONMENTAL PARAMETERS WITHIN LIMITS

2.5 RECORD EXPERIMENT DATA; CHECK REAL-TIME DATA PROCESSING; ANALYZE & VERIFY RECORDED DATA

0.5 ACTIVATE ELECTROPHORETIC APPARATUS; VERIFY APPARATUS IS OPERATING; CHECK FOR PROPER COMMAND RESPONSE, DATA TRANSMISSION, VOLTAGE, CURRENT, ETC.

0.5 ACTIVATE CAMERA/MICROSCOPE; CHECK CAMERA OPERATION, SEQUENCING, FILM ADVANCE, ETC. VERIFY MICROSCOPE OPERATION, ADJUSTMENT, ETC.

0.5 ACTIVATE CENTRIFUGE; VERIFY PROPER OPERATION, SPIN RATE, ETC.

TOTAL TIME = 4.25 HOURS

0.75 POWER DOWN & SECURE EQUIPMENT

MB-4 BIOLOGICAL CELL ELECTRICAL CHARACTERISTICS

0.75 SET UP EXP EQUIP & ACTIVATE SUPPORT EQUIP (GSE, POWER DIST SYS, TAPE RECORDER, C&W SYS, ETC.)

0.25 ACTIVATE CONTROL & DISPLAY CONSOLE

1.5 MONITOR OPERATION OF C&D CONSOLE; CHECK FOR PROPER COMMANDS, TALKBACKS, DISPLAYS, & EXPERIMENT DATA PROCESSING

1.0 ACTIVATE REFRIGERATOR; CHECK FOR PROPER TEMP, DISPLAYS, ETC. VERIFY PERTINENT ENVIRONMENTAL PARAMETERS WITHIN LIMITS

1.0 ACTIVATE INCUBATOR; CHECK FOR PROPER POWER, TEMP, DISPLAYS, ETC. VERIFY PERTINENT ENVIRONMENTAL PARAMETERS WITHIN LIMITS

1.5 RECORD EXPERIMENT DATA; CHECK REAL-TIME DATA PROCESSING; ANALYZE & VERIFY RECORDED DATA

0.5 ACTIVATE CAMERA/MICROSCOPE; CHECK CAMERA OPERATION, SEQUENCING, FILM ADVANCE, ETC. VERIFY MICROSCOPE OPERATION, ADJUSTMENTS, ETC.

0.5 POWER DOWN AND SECURE EQUIPMENT

TOTAL TIME = 3.0 HOURS

MB-5 BIOLOGICAL CELL PROPERTIES

0.25 ☐ ACTIVATE EXPMT SUPPORT EQUIP (GSE, SUPPORT ELECTRONICS, ETC.)

0.25 ☐ ACTIVATE CONTROL & DISPLAY CONSOLE & EXPERIMENT COMPONENTS

1.0 MONITOR OPERATION OF C&D CONSOLE & EXPERIMENT TIMER; CHECK FOR CORRECT SENDING OF SIGNALS TO THE SAMPLING UNIT

0.5 ACTIVATE EXPMT MODULE AIR SAMPLING UNIT; CHECK FOR ADEQUATE VENTILATION OF SAMPLING UNIT & VERIFY SAMPLES TAKEN ARE REPRESENTATIVE OF EM ENVIRONMENT

0.5 REPEAT THE PROCEDURE ABOVE FOR AIR SAMPLING UNIT IN THE ORBITER CABIN

0.25 ☐ INSPECT THE REFRIGERATOR TO ASSURE THAT AIR SAMPLE CULTURES WILL FIT & TEMPERATURE MAINTAINED IS CORRECT

0.25 ☐ POWER DOWN & SECURE EQUIPMENT

TOTAL TIME = 2.0 HOURS

EN-1 SAMPLING OF AIRBORNE PARTICLES AND MICRO-ORGANISMS IN SPACE CABIN ENVIRONMENT

0.50 ACTIVATE EXP SUPPORT EQUIP (GSE, SUPPORT ELECTRONICS, TAPE RECORDERS, ETC.)

0.25 ACTIVATE CONTROL & DISPLAY CONSOLE & EXPERIMENT COMPONENTS

0.25 INSPECT FATIGUE TESTER MOUNTING PLATE FOR PROPER INSTALLATION AND POSITION IN AIRLOCK

0.5 ACTIVATE FATIGUE TESTER EXTENSION MECH; PARTIALLY DEPLOY EXTENSION BOOM TO VERIFY PROPER OPERATION & CLEARANCE OF AIRLOCK & ALL PALLET-MOUNTED EQUIP

2.0 ACTIVATE LOAD AND CYCLE COUNTER; MONITOR OPERATION DURING TESTING OF FATIGUE TEST MACHINE; CHECK FOR CORRECT DATA XMISSION FOR REF STD FATIGUE TEST SPECIMEN

2.0 MONITOR OPERATION OF C&D CONSOLE; CHECK FOR CORRECT SENDING/RECEIVING OF SIGNALS TO/FROM EXP COMPONENTS

2.5 MONITOR DATA RECORDING; ANALYZE & CHECK RECORDED DATA; VERIFY PROPER DATA RECORDING RATE & CAPACITY

1.0 ACTIVATE FATIGUE TEST MACHINE; CHECK OPERATION WITH REFERENCE STANDARD FATIGUE TEST SPECIMENS

1.0 ACTIVATE CRACK PROPAGATION MONITORING UNIT; CHECK OPERATIONS WITH REF STD FATIGUE TEST SPECIMENS

0.5 SHUT DOWN & SECURE EQUIPMENT

TOTAL TIME = 4.5 HOURS

EN-2 ORBITAL FATIGUE EXPERIMENT

Space Division
Rockwell International

0.25 ☐ ACTIVATE EXPMT & SUPPORT EQUIP (GSE, TAPE RECORDERS, ETC.)

0.5 VERIFY INTEGRITY OF VACUUM CHAMBER

0.25 ☐ ACTIVATE VAC CHAMBER DOOR RELEASE MECH; VERIFY CLEARANCE OF ALL PALLET-MOUNTED EQUIP BY DOOR AS IT OPENS; ACTIVATE DOOR CLOSING COMMAND; CHECK THAT DOOR CLOSES & HAS PROPER CONTACT & SEAL

0.25 ☐ ACTIVATE EXTENSION BOOM; PARTIALLY DEPLOY BOOM & VERIFY CLEARANCE OF ALL PALLET-MOUNT EQUIP; RETRACT BOOM & CHECK FOR PROPER STOWAGE IN VAC CHAMBER; RE-EXTEND BOOM TO CHECK OUT OTHER COMPONENTS

0.25 ☐ ACTIVATE SAMPLE TRAY COVER MOTOR; OPEN & CLOSE TRAY COVERS TO VERIFY PROPER OPERATION

1.0 ACTIVATE SAMPLE ARRAY ROTATION MECH; EXERCISE FULL ROTATION CAPABILITY

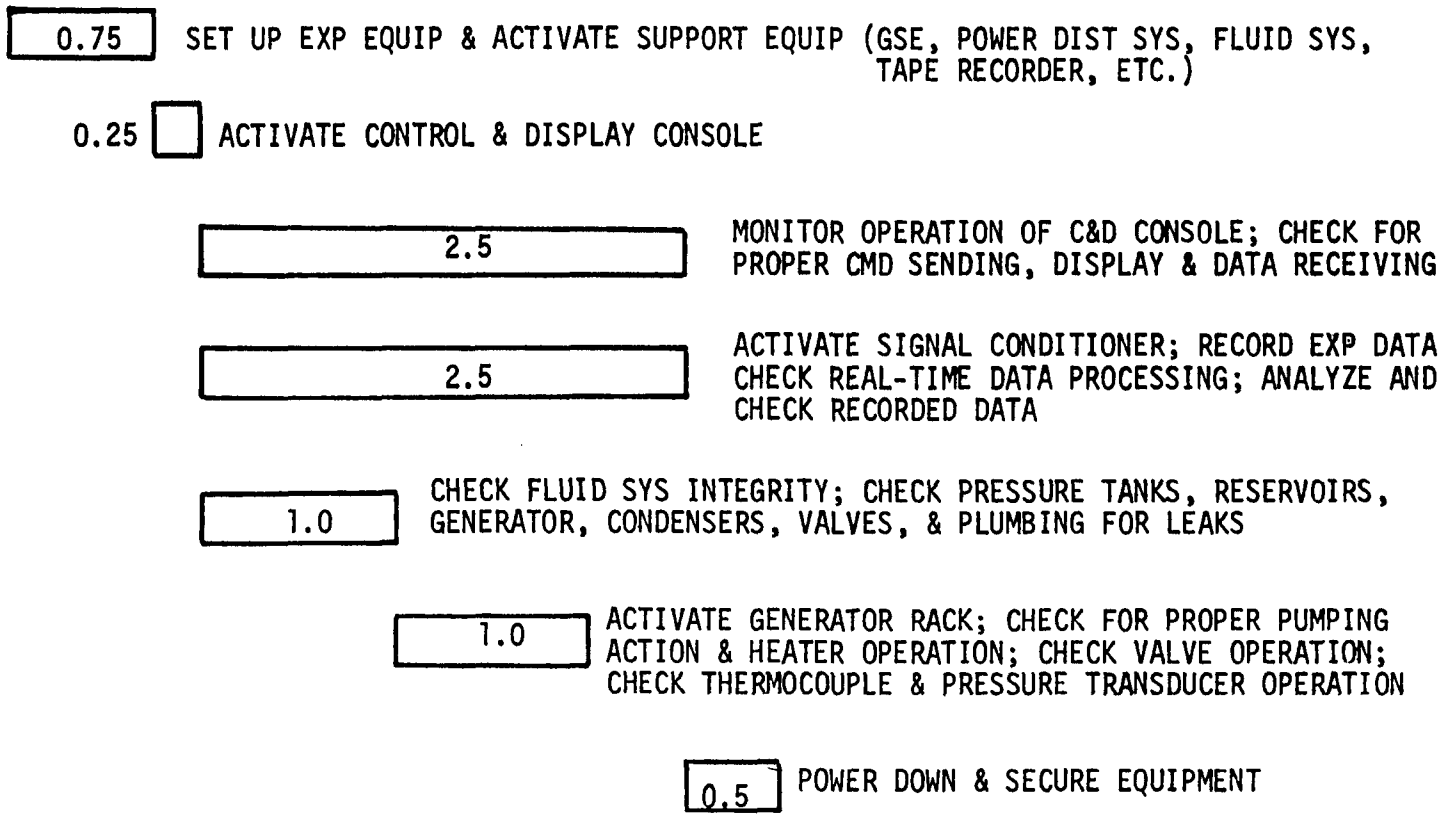
0.5 ACTIVATE SUN SENSORS; CHECK FOR PROPER RESPONSE & REF. ILLUM; VERIFY PROPER RESPONSE BY SAMPLE ARRAY ROTATION MECH TO SIGNALS FROM SUN SENSORS

0.5 ACTIVATE TEMP MEASUREMENT SENSOR; CHECK FOR PROPER DATA TRANSMISSION FOR AMBIENT ENVIRONMENT

0.75 MONITOR, ANALYZE & CHECK RECORDING OF RAW DATA FROM TEMP SENSORS; VERIFY CORRECT RECORDING RATES AND CAPACITY

TOTAL TIME = 3.75 HOURS

0.5 POWER DOWN & SECURE EQUIPMENT



TOTAL TIME = 4.0 HOURS

CS-2 ZERO-G STEAM GENERATOR

Space Division
Rockwell International

0.5 SET UP EXP EQUIP & ACTIVATE SUPPORT EQUIP (GSE, POWER DIST SYS, TAPE RECORDER, ETC.)

0.25 ACTIVATE CONTROL & DISPLAY CONSOLE

1.25 MONITOR OPERATION OF C&D CONSOLE; CHECK FOR PROPER COMMAND SENDING, TALKBACKS, DISPLAYS, AND RECEIPT OF EXPERIMENT DATA

0.5 OPERATE SENSOR COVER MECH; OPEN SENSOR COVER TO CHECK DEPLOYMENT MECH; CHECK FOR CLEARANCE BETWEEN COVERS & OTHER EQUIPMENT; CHECK FOR PROPER COMMAND RESPONSE, TALKBACKS, & DATA

1.25 RECORD EXP DATA; CHECK REAL-TIME DATA PROCESSING; ANALYZE AND CHECK RECORDED DATA

0.5 POWER DOWN & SECURE EQUIPMENT

TOTAL TIME = 2.5 HOURS

XST- CONTAMINATION MONITOR

Space Division
Rockwell International

APPENDIX C

C. EXPERIMENT SUMMARY

APPENDIX C. EXPERIMENT SUMMARY

Appendix C consists of a summary of the requirements for each experiment included in the study. These experiments are designed to further the development of new technology and to demonstrate the applicability of this space technology to meet the future needs of the nation. Major emphasis of these experiments is placed on the exploration of new concepts and instrumentation to obtain measurements which test analytical models and provide an engineering base for developing future operational systems. The primary source of the data presented in this appendix was NASA TM X-2813, "Study of Shuttle-Compatible Advanced Technology Laboratory (ATL)." A second major data source was the "Shuttle System Payload Description Activity (SSPDA)" reports of July, 1974. Where applicable, the experiment and equipment designations (e.g., XST001 and ST001) of SSPDA are indicated in the data.

NAVIGATION EXPERIMENTS

There are three experiments identified in the area of navigation. These experiments are application oriented but include analytical investigations and development of new instrumentation and techniques. The experiments are currently at different levels of development, ranging from conceptual definition, extensive analytical evaluation, ground-based hardware development and testing to planned aircraft flight measurement programs. All experiments utilize the Shuttle sortie mission capability to gain access to space as an observation platform.

EXPERIMENT NV-1 (XST001)

Microwave Interferometer Navigation and Tracking Aid

Objective. The purpose of this experiment is to determine the utility, limitations, and accuracy of a satellite interferometer technique at L-band for locating low-powered radio sources on the earth and on moving vehicles under a variety of weather conditions.

Description. This interferometer employs a technique developed to provide a means for determining position. This technique is useful in such applications as tracking, search and rescue, air-traffic surveillance and all-weather navigation. The experiment uses L-band frequency for achieving high-accuracy measurements without ionospheric perturbations to the signal and without the need for extensive calibration sites.

The experiment equipment consists of a vernier helicone antenna and preamplifier at each end of extendable orthogonal booms. Cables running along the boom connect the preamplifier with a radio receiver located at the hub of the boom mount. A second set of coarse helicone antennas are also located around the boom mount hub. The booms are retracted and stowed in canisters during launch and reentry operations.

The look angle of the target with respect to the baseline L (the distance between two receiving antennas) is determined from the geometry and the phase measurement established as a result of the propagation path difference

to the two antennas. The geometry is illustrated in Figure C-1. This establishes a target baseline. The use of orthogonal baselines provides for a second baseline with the target being at the intersection of these position lines. A block diagram of the single baseline system is shown in Figure C-2. Two systems are required.

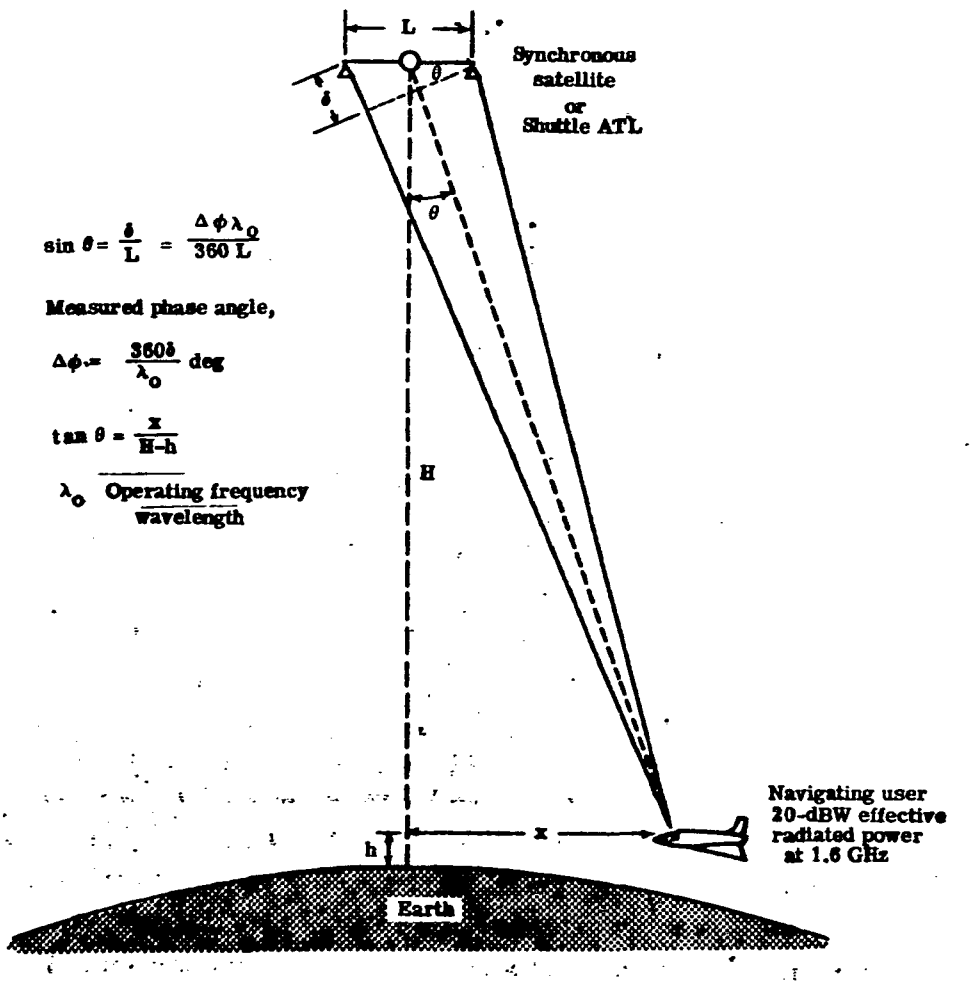


Figure C-1. Experiment Geometry

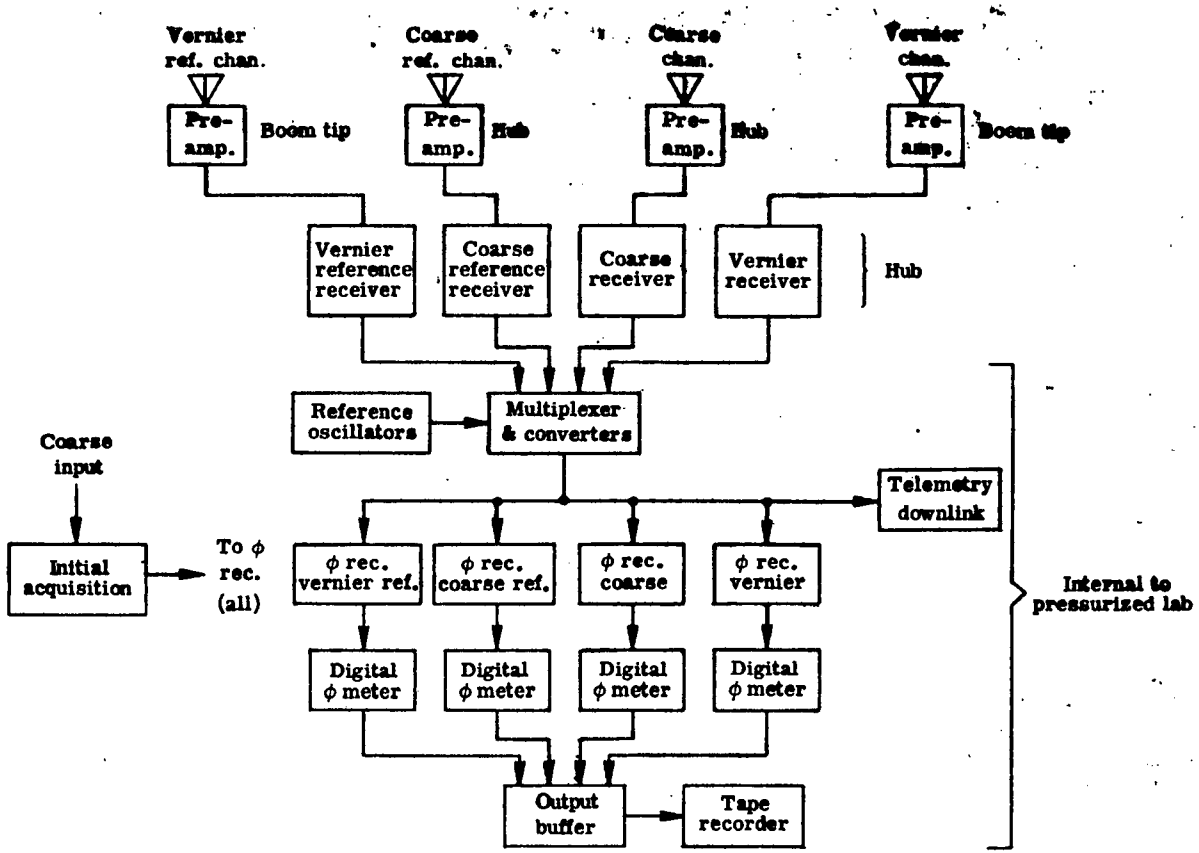


Figure C-2. Block Diagram of Single Baseline Interferometer (Two are required for ATL experiment.)

Space Division
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Physical Parameters - Experiment NV-1 (XST001)

Equipment		Qty	Location	Size (ft)			Vol (ft^3)	Wt (lb)
Ref. No.	Name			W/Dia	H	L		
ST001	Vernier Helicone Antenna	4	External	1.3	-	1.0	1.3	5.0
	Coarse Helicone Antenna	4	External	1.3	-	1.0	1.3	5.0
ST002	Vernier Preamplifier	4	External	1.0	1.0	1.0	1	5.0
	Coarse Preamplifier	4	External	1.0	1.0	1.0	1	5.0
ST003	Extendable Boom and Canister	4	External	1.5	-	6.0	10.6	65
ST004	Boom Mount	1	External	4.0	-	6.0	75.4	150
ST005	Receiver	8	External	.8	.8	.8	.5	7.0
ST006	Electronics	2	Internal	.9	.9	.9	.73	10.0
ST007	Oscilloscope	1	Internal	1.6	.6	1.5	1.44	29
ST008	Digital Tape Recorder	1	Internal	1.6	.9	1.6	2.3	100
ST010	Output Buffers	2	Internal	.9	.9	.9	.73	10
ST011	Vernier Dig Dis & Rec	2	Internal	1.6	1	1.6	2.56	10
	Coarse Dig Dis & Rec	2	Internal	1.6	1	1.6	2.56	10
ST012	Boom Controls	1	Internal	1.0	1.0	1.0	1	10
ST020	Control and Display Console	1	Internal	1.6	1.0	1.0	1.6	20

Configuration - Internal details, see Figure C-3; external details, see Figure C-4.

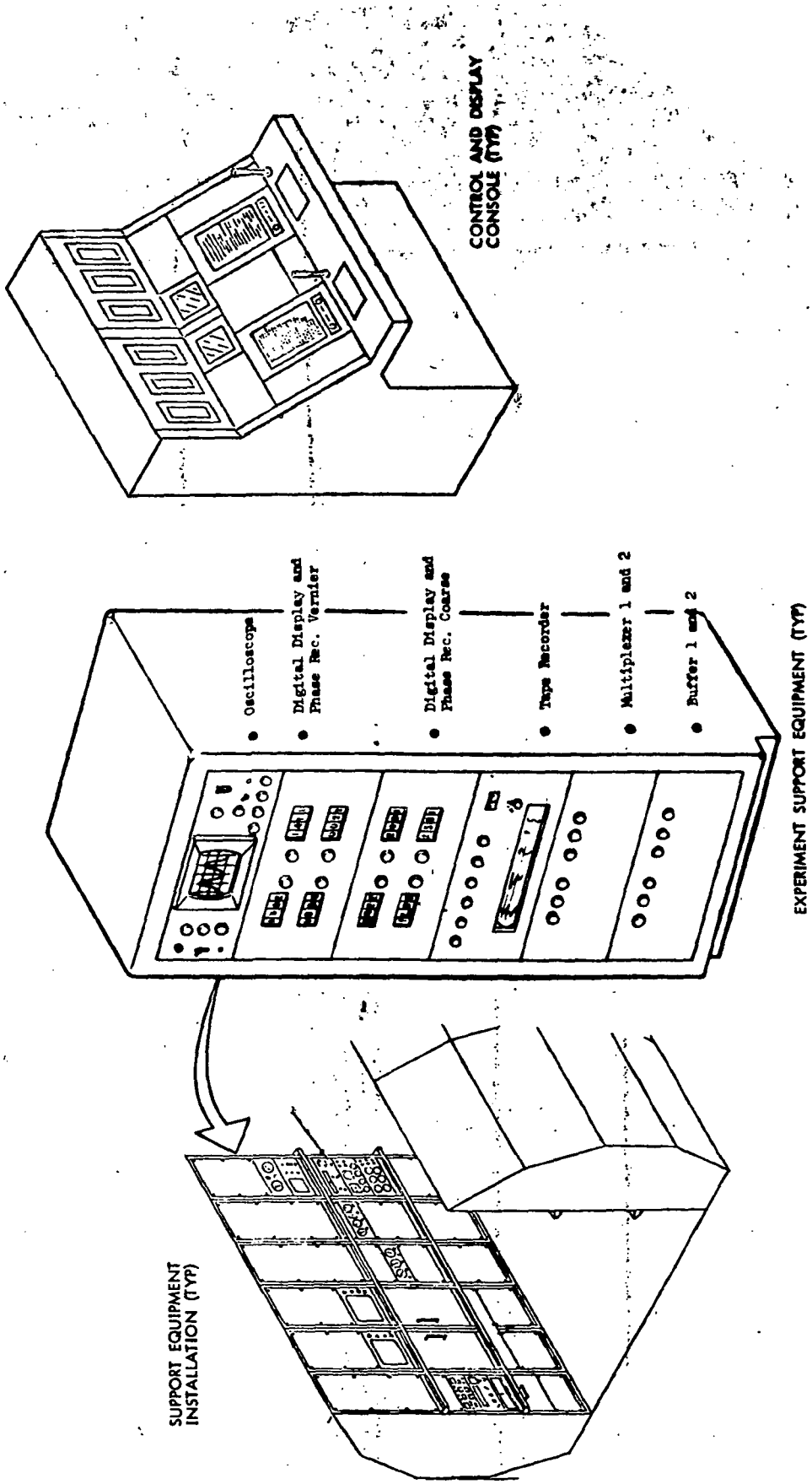


Figure C-3. Experiment Module Installed Equipment

Figure C-4. Pallet-Installed Equipment

Electrical/Data Requirements - Experiment NV-1 (XST001)

Equipment		Power (W)		Data	
Ref.No.	Name	Stdby	Operate	Form	Rate
ST001	Antenna	-	-	-	-
ST002	Preamplifier	10	10	A	
ST003	Extendable Boom	0	-	-	-
ST004	Boom Mount	0	100	-	-
ST005	Receiver	10	10	A	
ST006	Electronics	10	10	D	3 MBPS
ST007	Oscilloscope	30	92	CRT	-
ST008	Digital Tape Recorder	25	250	D	
ST010	Output Buffer	10	10	D	3 MBPS
ST011	Dig Display & Receiver	15	15	Visual	-
ST012	Boom Controls	10	10	-	-
ST020	Control & Display Console	10	10	-	-

Pointing and Stability - Experiment NV-1 (XST001)

Equipment		Pointing Requirements/Capability			
Ref.No.	Name	Accuracy (deg)	Duration (sec)	Stability (deg)	Stability Rate (deg/sec)
Shuttle Pointing					
ST001	Coarse Antenna	0.5	1800	0.5	0.1
	Vernier Antenna	0.5	1800	0.5	0.1
Instrument Pointing					
ST001	Coarse Antenna	-	-	-	-
	Vernier Antenna	0.5	180	0.5	.006

Field of View. Orthogonal boom structure should clear the tail of the Shuttle and other experiment structures and be shielded from thermal dump. Antenna must have unobstructed RF view of ground position. Static position of boom should be maintained within 2 degrees, and a stability rate of 10^{-5} radians/sec during 10-second measurement times is required.

Mission Operations. Instrument to be operated from 100 to 300 nmi altitude over known target and calibration ranges.

EVA Activity. None planned.

Crew Function. Initiate and monitor boom and antenna deployment; check out, test and calibrate equipment; monitor signals during data runs; coordinate the experiment with test vehicles and ground stations; secure data recordings; shut down equipment; and store booms and antennas for reentry and return flight.

Consumables.

Magnetic tape (5 lb, 0.1 ft^3)
Film, none
Cryogenics, none

Environmental Requirements

Operational State	Temp (°K)	Rel. Hum. (%)	Cleanliness (Class)	Acoustics (dB)	Acceleration (g)
Operating					
Internal Equipment	295 ± 5	55 ± 25	300,000	60	.001
External Equipment					
Non-Operating					
Internal Equipment	295 ± 20	50 ± 45	300,000	145	9.0
External Equipment	283 ± 83		300,000	145	9.0

Development Status. Analytical studies have been completed and ground-based simulation using breadboard hardware is in progress at the Federal Systems Division of IBM under Contract NAS1-10997.

EXPERIMENT NV-2 (XST004)

Autonomous Navigation

Objective. The purpose of this experiment is (1) to determine the utility, limitations, and accuracy of a number of navigation techniques for determining orbital position relative to earth ground track under identifical environmental conditions; (2) to measure sensor accuracy and overall system error to aid in testing analytical error models under a variety of environmental conditions; and (3) to flight-test a holographic starfield/landmark tracker and ground beacon tracker.

Description. This experiment examines a number of techniques and/or instruments including the use of star-horizon tracking, known landmark tracking, unknown landmark tracking, ground beacon tracking, and combinations of these for on-board autonomous navigation. These techniques are autonomous in that minimal ground support is required.

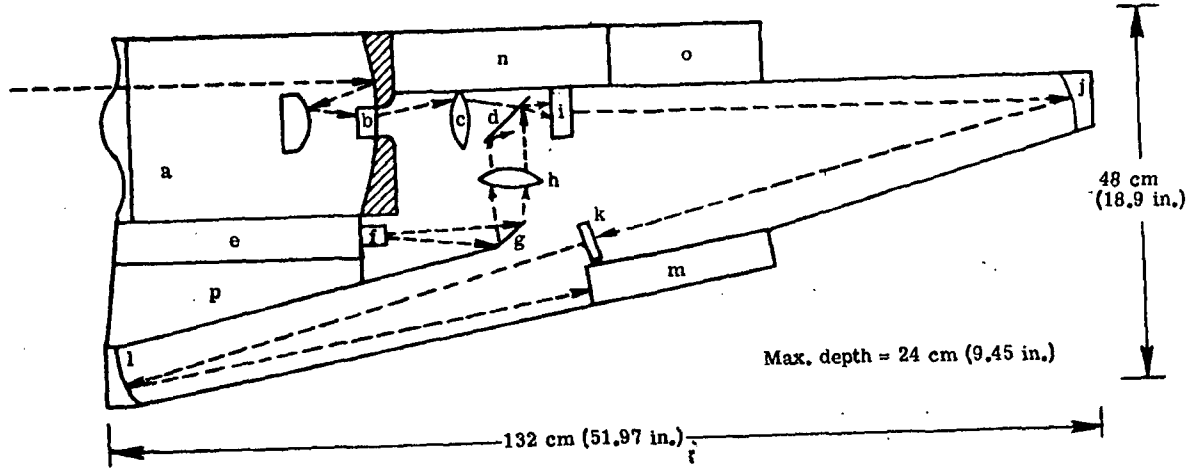
The ground tracking network, along with other Shuttle navigation aids will be used to provide precise location and attitude reference standards for assessing instrument and system errors. Environmental conditions such as lighting, thermal state, landmark contrast, and atmospheric conditions will be monitored to provide correlation data for performance assessment. A TV camera provides real-time viewing for boresighting sensors and for visual monitoring of target tracking. Beacon tracking will be performed along with interferometer and/or doppler shift measurements. Landmark and starfield tracking will be performed with a tracker employing a holographic spatial filtering technique.

The experiment utilizes a single telescope which is time-shared for both starfield and landmark tracking and is coupled to a coherent optical parallel image correlator with an inertial reference unit. The equipment is mounted within a platform assembly that presumes a Shuttle roll maneuver for target viewing. The autonomous navigation experiment is shown in Figures C-5 and C-6. A block diagram of the starfield and landmark tracker is illustrated in Figure C-7.

The holographic starfield and landmark tracker uses a 20-cm clear aperture Schmidt-Cassegrain telescope with an 8-degree field of view, a 1-watt H_e-N_e laser, a 25-mm wafer image intensifier, paraboloidal mirror segments, fixed multiplexed matched spatial filter, image dissector electro-optical readout system, and an optical-to-optical input imaging device.

Two basic modes can be tested with this design--determination of vehicle ephemeris and vehicle attitude.

For ephemeris determinations, measurements are taken by starfield and landmark tracking on a time-shared basis using the inertial system for reference data to compare correlation functions. Measurement sampling periods



a Schmidt-Cassegrain telescope
b Wafer-type image intensifier
c Transfer lens
d 80:20 beam splitter
e He-Ne laser
f Pinhole and microscopic objective
g Beam deflection mirror
h Collimating lens
i Optical-to-optical interface ("OTTO")
j 1st Fourier transform mirror
k Multiplexed matched spatial filter
l 2nd Fourier transform mirror
m Image dissector readout
n Image dissector electronics
o "OTTO" power supply
p Laser power supply

Figure C-5. Conceptual Design of Holographic Starfield and Landmark Tracker

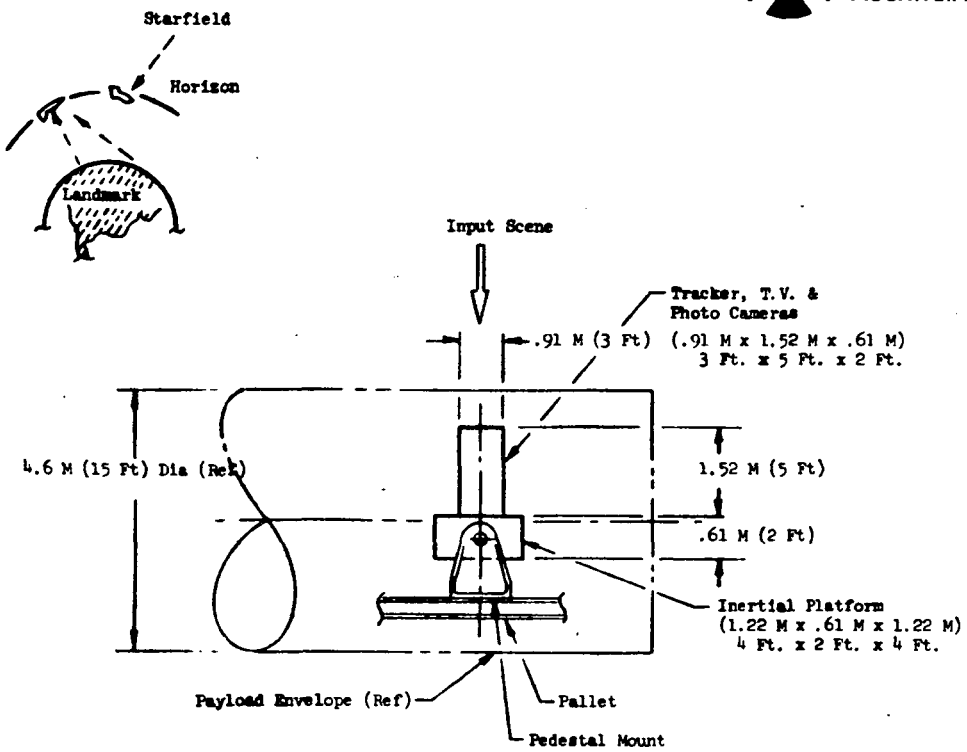


Figure C-6. Pallet-Installed Equipment

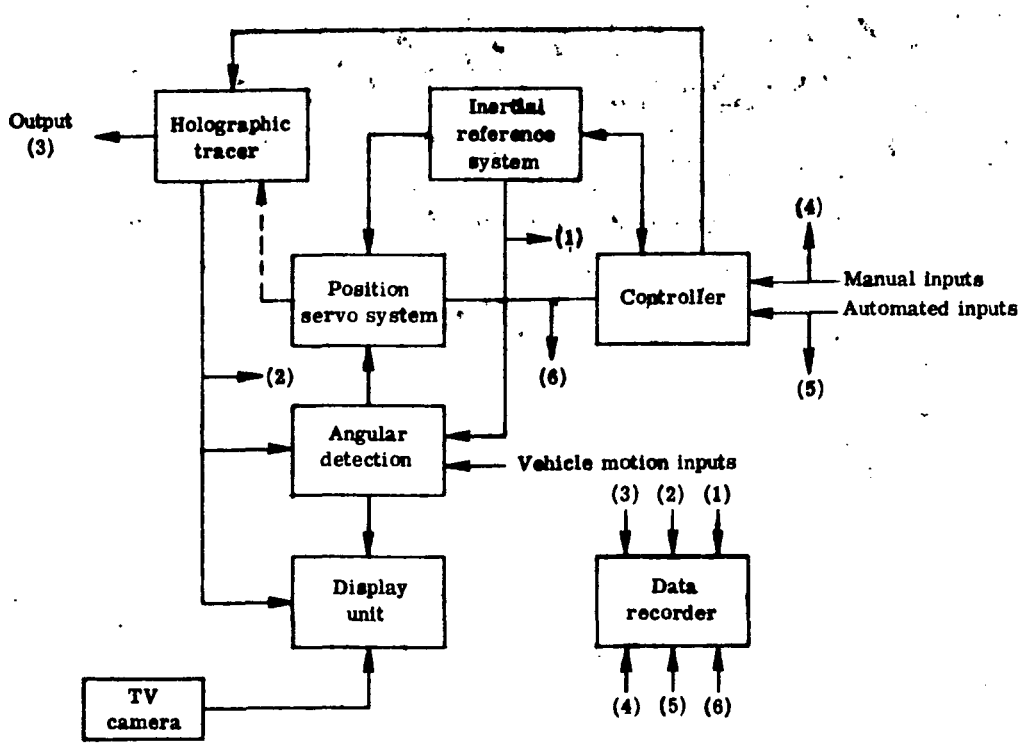


Figure C-7. Block Diagram of Starfield and Landmark Tracker Experiment

from 3 minutes up to a few hours are desirable with studies indicating about 5-minute intervals between measurements as optimum. The measurement interval time will be varied over a wide range to provide data for determining minimum error as a dependent variable. Inertial platform update may be performed along with real-time position determination.

For vehicle attitude determination, the inertial system will be caged and starfield tracking maintained to determine 3-axis vehicle attitude. Measurements will be made over the sampling period range of 0.005 to 1.0 second to determine minimum error performance.

Physical Parameters. Experiment NV-2 (XST004)

Equipment				Size (ft)			Vol	Wt
Ref.No.	Name	Qty	Location	W/Dia	H	L	(ft^3)	(lb)
ST019	Still Camera	1	External	*	*	*	*	*
ST007	Oscilloscope	1	Internal	1	1	1	1	29
ST008	Tape Recorder	1	Internal	1.6	.9	1.6	2.3	100
ST021	Starfield/Landmark Tracker	1	External	3	5	2	30	50
ST022	Ground Tracker	1	External	*	*	*	*	*
ST023	Inertial Platform	1	External	4	4	2	32	300
ST024	Computer	1	Internal	1.6	1	2	3.2	111
ST025	TV Camera	1	External	*	*	*	*	*
ST026	TV Display	1	Internal	1	1	1.5	1.5	25
ST027	Spatial Filters		External	*	*	*	*	*
ST028	Control and Display Console	1	Internal	1	1	2	2	50
ST029	Telescope	1	Internal	*	*	*	*	*
ST030	Coherent Optical Image Correlator	1	External	*	*	*	*	*
ST031	Experiment Platform	1	External	6	6	2	72	200
ST032	Laser Transmitter	1	External	*	*	*	*	*

*Included in ST021

Configuration. (see Figure C-6)

Electrical/Data Requirements. Experiment NV-2 (XST004)

Equipment		Power (W)		Data	
Ref. No.	Name	Stby	Operate	Form	Rate
ST007	Oscilloscope	30	92	CRT	-
ST008	Tape Recorder	25	250	D	
ST019	Still Camera	0	5	Film	-
ST021	Starfield/Landmark Tracker	20	40	D	2 MBPS
ST022	Ground Tracker	-	-	D	
ST023	Inertial Platform	100	100	-	-
ST024	Computer	100	800	D	-
ST025	TV Camera		100	D	
ST026	TV Display	300	300	-	-
ST027	Spatial Filters	-	-	-	-
ST028	Control and Display Console	120	120	Display	-
ST029	Telescope	-	-	-	-
ST030	Correlator	-	-	-	-
ST031	Experiment Platform	-	-	-	-
ST032	Laser Transmitter	-	-	-	-

Pointing and Stability Requirements: None

Field of View. Pallet-mounted instruments require an unobstructed optical field-of-view and must be shielded from optical contamination.

Equipment		Field-of-View (Deg)	
Ref. No.	Name	Instantaneous	Total
ST021	Holographic Starfield & Landmark Tracker	8	8
ST025	TV Camera	36	-
ST029	Telescope	-	8

Mission Operation. Experiment to be performed from 100 to 300 nmi altitude with ground track over known landmark target sites. Starfield tracking is to be performed 4 times per day, 24 times per mission. Earth tracking is to be performed 5 times per day, 30 times per mission. This experiment requires coordination with other experiments and with meteorological measurements. Use of Shuttle systems to obtain navigation data is required as well as on-board processing or storage of photographic film.

EVA Activity. None.

Crew Function. Deploy equipment; set up, test and calibrate instruments; select targets and spatial filters; monitor output signal during data-taking intervals; select measurement intervals, coordinate with ground stations and other experiments; operate data recorders and secure data storage; and shut down equipment and secure for reentry and return flight.

Consumables. Magnetic tape
Film (10 lb, 0.2 ft^3, 70 mm)
Cryogenics

Environmental Requirements - NV-2 (XST004)

Operational Status	Temp (°K)	Rel. Hum. (%)	Cleanliness (Class)	Acoustics (dB)	Acceleration (g)
Operating					
Internal Equipment	295 ± 5	55 ± 25	300,000	60	.001
External Equipment					
Non-Operating					
Internal Equipment	295 ± 20	50 ± 45	300,000	145	9.0
External Equipment	283 ± 83		300,000	145	9.0

Development Status. The holographic starfield and landmark tracker is currently being developed and evaluated by the General Electric Company under contract NAS1-10739.

EXPERIMENT NV-3 (XST007)

Multipath Measurements

Objective. The purpose of this experiment is (1) to measure the statistical properties of signals received simultaneously over multiple propagation paths between Shuttle vehicles and relay satellites; (2) to determine the utility of an analytical multipath model for predicting signal fading; and (3) to obtain environmental information on the design of spacecraft antennas for use with relay satellites.

Description. Radio-frequency signals transmitted between low earth-orbiting vehicles and geosynchronous communication relay satellites are troubled with multipath transmission. Different propagation delays for each of the multipaths result in the receipt of a compound signal having partial signal cancellation and a reduced signal-noise ratio.

This experiment employs the spatial modulation extrapolation technique to investigate this phenomena. Four interacting effects are considered: (1) range-dependent loss, (2) multipath cancellation loss, (3) multiplicative noise, and (4) intersymbol interference.

Multipath fading is most degrading when different propagation paths approach equal length, i.e., over horizon-to-horizon range. Multiplicative noise is most degrading for high grazing angles of the reflected wave. Omnidirectional antenna systems and polar missions experience high signal degradation due to multipath reflections from the earth's surface regardless of antenna directivity.

In this experiment, a transmitter located on a geosynchronous satellite will transmit a set of sinusoidal carriers to the receiver system on the Spacelab. Measurements will be made at various frequency bands with special attention given to S-band and Ku-band frequencies. The specific carrier frequencies being considered are L-band (1.5 to 1.6 GHz), S-band (2.025 to 2.3 GHz) and Ku-band (13.4 to 15.35 GHz).

Experiment data will be used to verify the analytical multipath model used in the design and prediction of multipath-tolerant hardware. The model has been verified using aircraft flight test data. The Shuttle-to-satellite data are required, however, to further verify the model and to develop confidence that it is applicable to space communication systems where the vehicle velocity is greatly increased.

Physical Parameters. NV-3 (XST007)

Equipment		Qty	Location	Size (ft)			Vol. (ft^3)	Wt (lb)
Ref.No.	Name			W/Dia	H	L		
ST009	Analog Tape Recorder	1	Internal	1.6	.9	1.6	2.3	100
ST127	RF Receiver	1	Internal	1.6	.5	1.25	1	15
ST128	Antenna Mount	1	External	7*	-	9*	346*	**
ST129	Electronics	1	Internal	2	3	3	18	100
ST275	Antenna	1	External	6.5	-	.167	5.53	50

**Weight included in antenna weight (ST275)

*Includes antenna stowage. Deployed to 10.5 ft with .75 ft diameter column on 4-ft pedestal.

Configuration. Not available.

Electrical/Data Requirements. NV-3 (XST007)

Equipment		Power (W)		Data	
Ref. No.	Name	Stdby	Operate	Form	Rate
ST009	Analog Tape Recorder	25	250	A	-
ST127	RF Receiver	-	50	A	
ST128	Antenna Mount				
ST129	Electronics	-	100	-	-
ST275	Antenna	-	-	-	-

Pointing and Stability Requirements. NV-3 (XST007)

Equipment		Pointing & Stability			
Ref. No.	Name	Accuracy (deg)	Duration (sec)	Stability (deg)	Stab. Rate (deg/sec)
Shuttle Pointing Req					
ST128	Antenna Mount	.5	1800	.5	.5
Mount Pointing Req*					
ST128	Antenna Mount	.5	1800	.5	.5
Instrument Pointing Cap					
ST128	Antenna Mount	.5	1800	.5	.5
*Accuracy required at inner gimbal.					

Field of View. TBD

Mission Operation. Experiment is to be conducted from a 100 to 300 nmi altitude orbit at an inclination of 60 to 90 degrees. Experiment is to be performed 2 times per day, 10 times per mission. There are approximately 4 viewing opportunities per day. Measurements are to be taken over various terrains and ocean areas.

EVA Activity. None.

Crew Functions. Deploy antenna and perform system checkout; calibrate and test equipment; select desired frequency band and coordinate with transmitter source; steer antenna; initiate, operate, and monitor recordings; observe and record meteorological conditions; and adjust equipment as required to complete measurements.

Consumables.

Magnetic tape, 5 lb; 0.1 ft^3
Film, none
Cryogenics, non

Environmental Requirements. NV-3 (XST007)

Operational Status	Temp (°K)	Rel. Hum. (%)	Cleanliness (Class)	Acoustics (dB)	Acceleration (g)
Operating					
Internal Equipment	295 ± 5	55 ± 25	300,000	60	.001
External Equipment					
Non-Operating					
Internal Equipment	295 ± 20	50 ± 45	300,000	145	9.0
External Equipment	283 ± 83		300,000	145	9.0

Development Status. The receiver, antenna and recorders could be developed within an 18- to 30-month time period.

EARTH OBSERVATION EXPERIMENTS

Nine experiments have been identified in the area of earth observations. The experiments include the application of laser technology to environmental measurement problems, application of solid-state spectral scanner technology to coastal zone oceanography, and the use of the Shuttle to deliver atmospheric and oceanographic sensors to remote regions of the earth.

EXPERIMENT EO-1 (XST010)

Lidar Measurements of Cirrus Clouds and Lower Stratospheric Aerosols

Objective. The purpose of this experiment is to measure the spatial distribution of cirrus clouds and lower stratospheric aerosols.

Description. This Lidar system consists of a pulsed laser transmitter monostatically aligned with a receiving telescope. The output of the telescope is optically filtered, detected by a photodetector, and recorded. A camera, boresighted with the nadir-pointed Lidar, provides photographic coverage of the clouds. Cirrus cloud altitudes, derived from the Lidar in conjunction with the photographs, will be used to generate three-dimensional cloud maps. In addition the position, heights and scattering function profiles of lower stratospheric aerosols will be determined.

The maps obtained from the Lidar will provide the data required to (1) permit accurate, long-term weather forecasting; (2) minimize the error in radiometric determinations of temperature from space; and (3) permit understanding of the importance of the high solar radiation reflectivity of cirrus clouds on the earth heat budget.

The data obtained on the aerosol distribution in the lower stratosphere will permit an understanding of its effect on the atmospheric albedo and radiometric data.

The block diagram of the Lidar measurement experiment is shown in Figure C-8. The instrument package is illustrated in Figures C-9 and C-10.

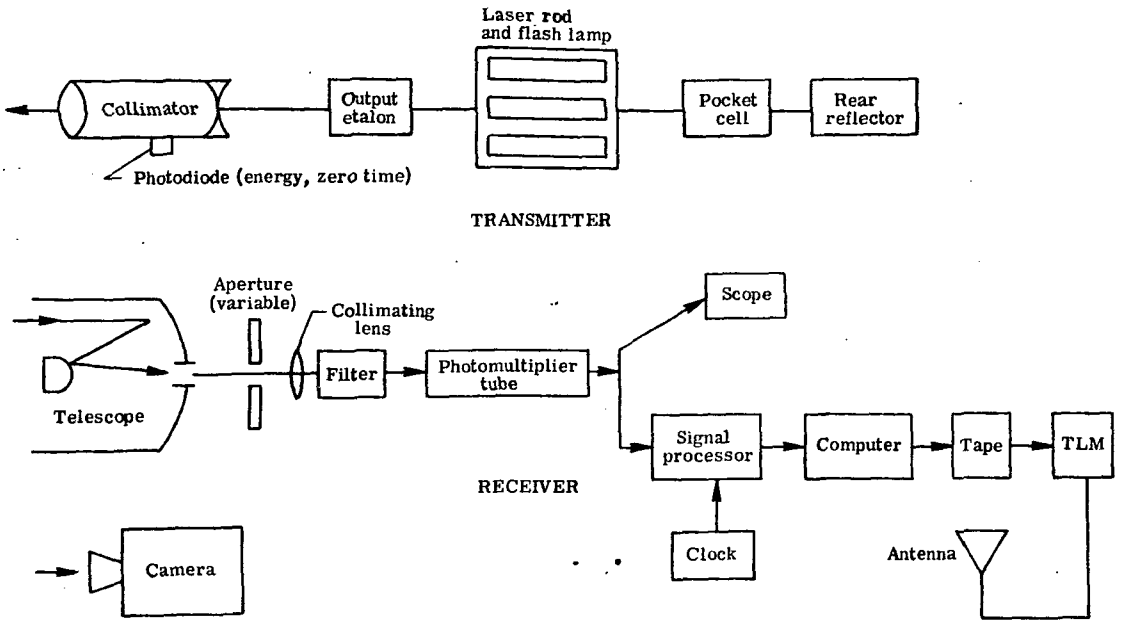


Figure C-8. Block Diagram of Lidar Measurements Experiment

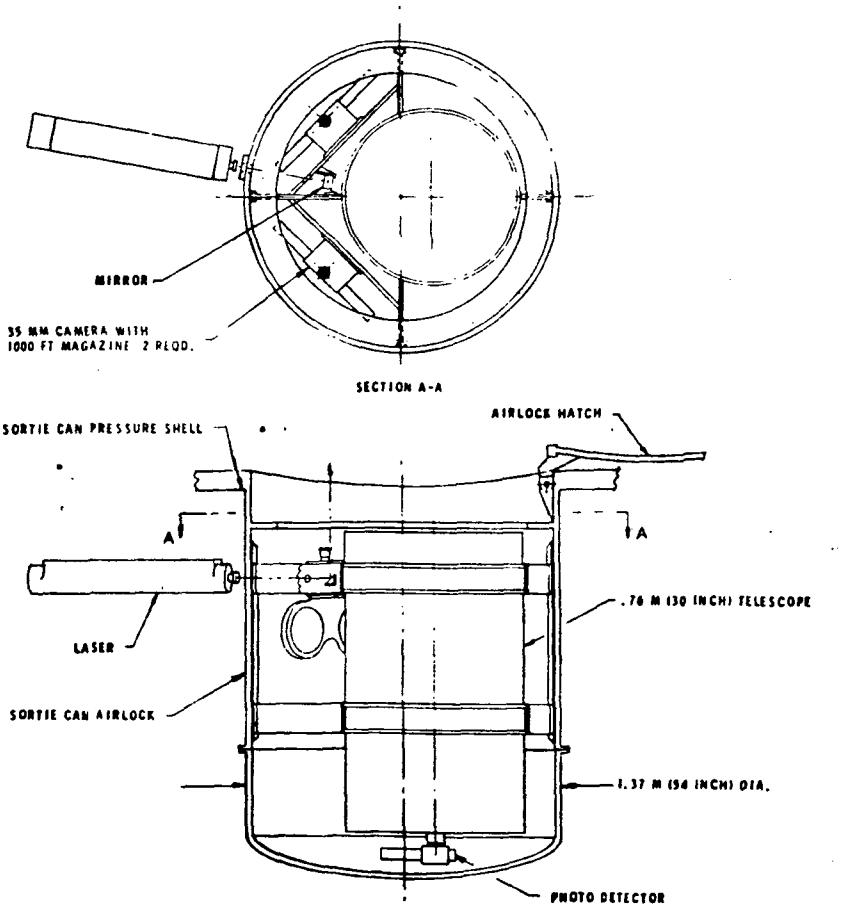


Figure C-9. Lidar Measurement Experiment Instrument

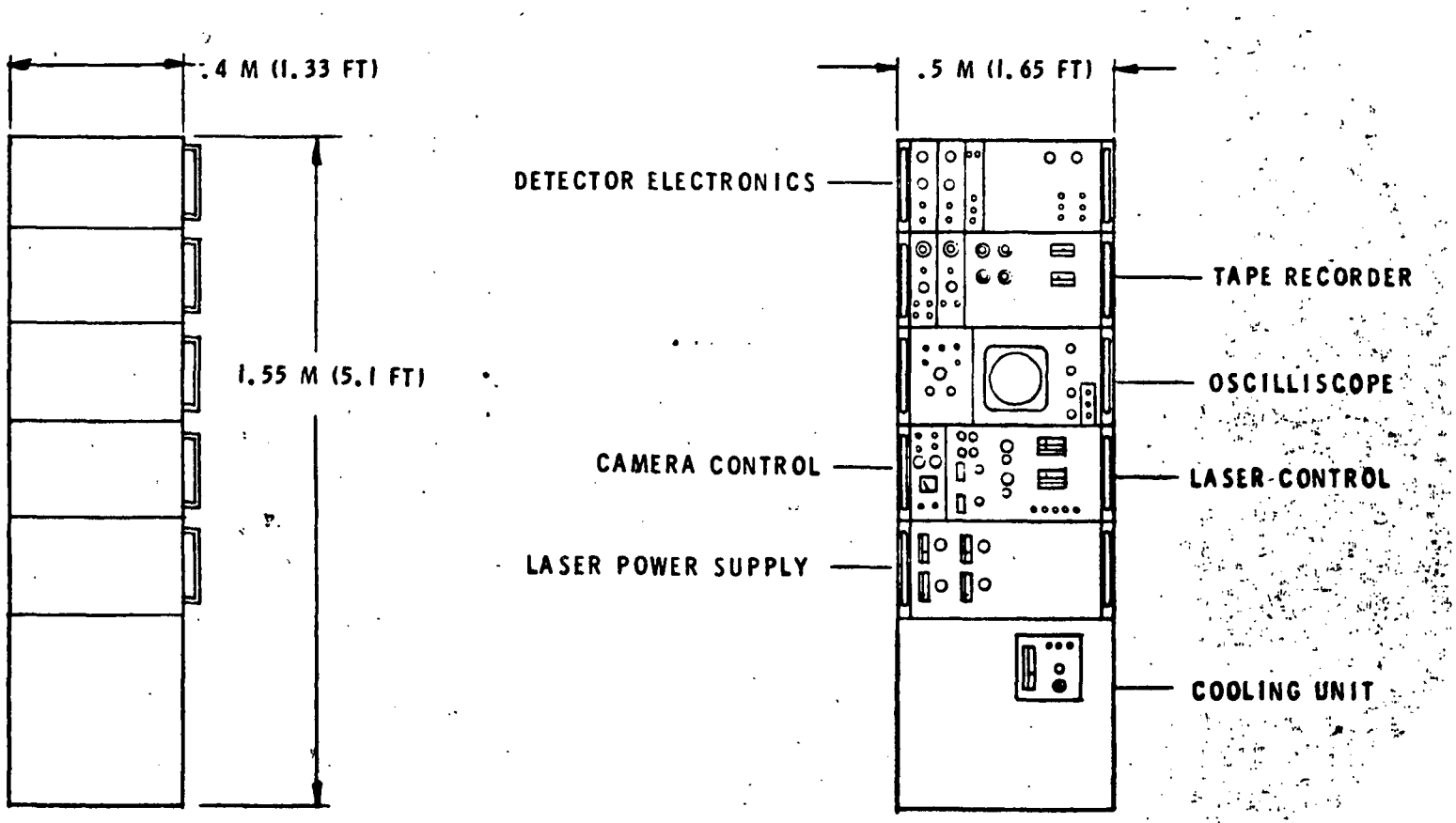


Figure C-10. Experiment Module Installed Equipment

Space Division
Rockwell International

Physical Parameters. EO-1 (XST010)

Equipment		Qty	Location	Size (ft)			Vol (ft^3)	Wt (lb)
Ref.No.	Name			W/Dia	H	L		
ST007	Oscilloscope	1	Internal	1.6	.6	1.5	1.44	29
ST008	Digital Tape Recorder	1	Internal	1.6	.9	1.6	2.3	100
ST024	Computer	1	Internal	2	2	2	8	160
ST035	Data Processing Equip	1	Internal	1	1	1	1	10
ST054	35 MM Cine Camera	2	External	.5	1	1	.5	20
ST132	Lidar Transmitter	1	External	3.3	-	3.8	32.5	500
ST133	Receiving Telescope	1	External	2.5	-	4.3	21.1	150
ST134	C/D Console	1	Internal	2	3	2.5	15	60
ST135	Housing	1	External	3.33	-	5	43.5	430

Configuration.

Internal details (See Figure C-10)
External details (See Figure C-9)

Electrical/Data Requirements. EO-1 (XST010)

Equipment		Power (w)		Data	
Ref. No.	Name	Stby	Operate	Form	Rate
ST007	Oscilloscope	30	92	Display	-
ST008	Digital Taper Recorder	25	250	D	-
ST024	Computer	-	50	-	-
ST035	Data Processing Equip	10	10	D	-
ST054	Cine Camera, 35 mm	-	50	Film	-
ST132	Lidar Transmitter	-	500	-	-
ST133	Receiving Telescope	-	20	A	-
ST134	C/D Console	-	50	Display	-
ST135	Housing	-	-	-	-

Pointing and Stability Requirements. EO-1 (XST010)

Equipment		Pointing & Stability			
Ref. No.	Name	Accuracy (deg)	Duration (sec)	Stability (deg)	Stab. Rate (deg/sec)
	Shuttle Pointing Req				
ST132	Transmitter	1	225	1	.1
ST133	Telescope	1	225	1	.1
	Mount Pointing Req				
ST132	Transmitter	1	225	1	.1
ST133	Telescope	1	225	1	.1
	Instr Pointing Cap				
ST132	Transmitter	1	225	1	.1
ST133	Telescope	1	225	1	.1

Field of View. Both the telescope and the cine camera have a 0.1-degree instantaneous field of view, and a 1.0-degree total field of view.

Mission Operation. The experiment is to be operated from polar orbit for global coverage. Any orbit, however, will provide meaningful data. The Spacelab is to be stabilized during experiment operation. The experiment must be pointed at nadir and the Spacelab longitude, latitude and altitude known within the accuracy of the Shuttle stability control system. Simultaneous Lidar and camera observations are to be made on the sun-lit side of the earth for the duration of the mission. Lidar observations only will be made on the dark side of the earth. Experiment is to be performed 16 cycles/day, 96 cycles per mission.

Crew Function. Experiment is fully automated. Crewman required to edit data and maintain equipment.

Consumables. Magnetic tape: 10 lb, 0.2 ft^3
Film: 10 lb, 0.2 ft^3, 35 mm
Cryogenics

Environmental Requirements. EO-1 (XST010)

Operational Status	Temp (°K)	Rel. Hum. (%)	Cleanliness (Class)	Acoustic (dB)	Acceleration (g)
Operating					
Internal Equipment	295 ± 5	55 ± 25	300,000	60	.001
External Equipment					
Non-Operating					
Internal Equipment	295 ± 20	50 ± 45	300,000	145	9.0
External Equipment	283 ± 83		300,000	145	9.0

Development Status. The development schedule for the experiment equipment through hardware fabrication and test is 5 years.

EXPERIMENT EO-2 (XST011)

Tunable Lasers

Objective. The purpose of this experiment is to develop a flight-qualified tunable injection laser monochrometer system for remote sensing of earth atmospheric constituents and pollutants and for *in situ* measurements of atmospheric constituents and pollutants interior to and near the spacecraft.

Description. Recent laser technology developments indicate that tunable laser techniques may provide a method of directly measuring the vertical distribution of pollutants from satellite altitudes by measuring the spectral line widths of the infrared absorption bands of pollutant molecules as a function of pressure.

Tunable lasers provide a means of concentrating large amounts of energy in narrow spectral lines which can be matched to the absorption lines of the pollutant. In the case of tunable injection lasers, these narrow spectral lines can be continuously tuned in wavelengths over a large spectral range (on the order of 1 to 10 mm). This allows increased spectral resolution by a factor of 10^3, and sensitivity by a factor of 10^4, over existing passive techniques.

The purpose of this experiment is to measure the vertical distribution of atmospheric pollutants using either a double-ended technique (tunable injection laser monochromator) or a single-ended technique (tunable laser heterodyne radiometer).

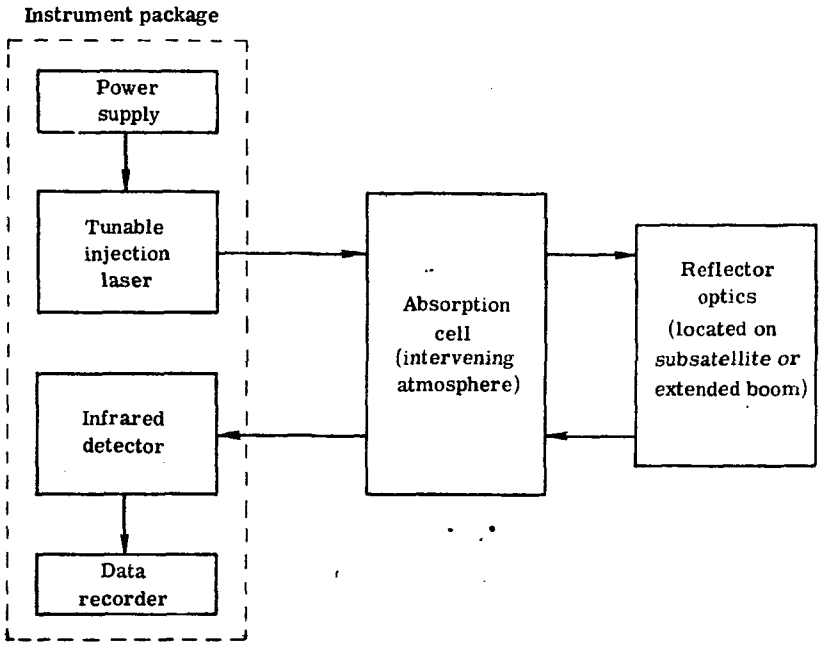
The double-ended technique, although more difficult to perform since it requires precise tracking and pointing, is attractive since laser absorption measurements in the infrared region have been demonstrated to be extremely sensitive.

The heterodyne technique is attractive since it represents a single-ended measurement, but it does require further laboratory studies to demonstrate feasibility with a tunable injection laser as a local oscillator.

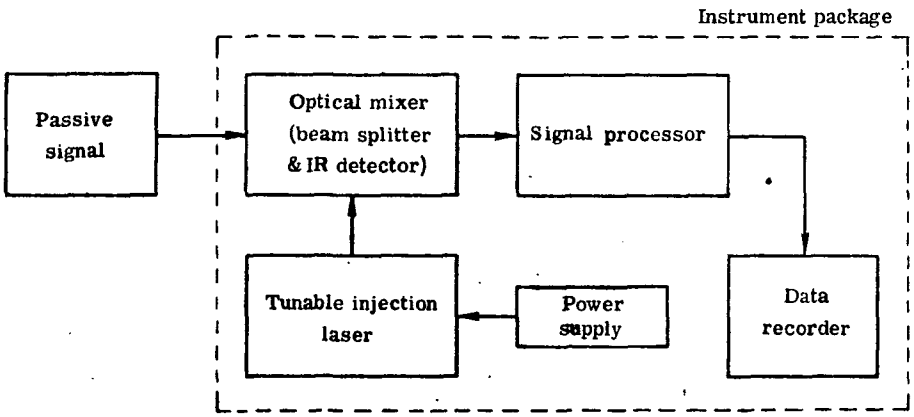
A secondary purpose of the experiment is to measure the atmosphere surrounding or interior to the Shuttle. A retroreflector on a boom and deployed from the Shuttle is required for the exterior measurements. The parameters to be measured are as follows.

1. Vertical distribution of atmospheric constituents and pollutants which contain absorption bands in the 2- or 3-micrometer region.
2. Spectroscopic parameters such as line shapes and line positions for use in computer modeling programs of the atmosphere.
3. Concentration of molecules in the atmosphere interior to and surrounding the Shuttle.

Block diagrams of the two configurations are shown in Figure C-11.



DOUBLE-ENDED ABSORPTION EXPERIMENT



TUNABLE LASER HETERODYNE RADIOMETER

Figure C-11. Block Diagram of Tunable Injection Laser Experiments

Physical Parameters. *EO2 (XST011)*

Equipment		Qty	Location	Size (ft)			Vol (ft^3)	Wt (lb)
Ref.No.	Name			W/Dia	H	L		
	Double-ended Absorption							
ST008	Data Recorder	1	Internal	1.6	.9	1.6	2.3	100
ST042	Boom	1	External	1	-	1*	.78	20
ST138	IR Detector	1	External	.4	-	1.5	.19	5
ST139	Cryogenics		External	1	-	3.8	3	100
ST136	Tunable Laser	1	External	1.5	-	2.3	4.05	50
ST141	C/D Console	1	Internal	2	3	2.5	15	60
ST277	Telescope, 24-inch	1	Internal	2	-	-	-	150
ST283	Power Supply, Laser	1	External	1.58	1.17	1.5	2.77	100
	Heterodyne Radiometer							
ST008	Data Recorder	1	Internal	1.6	.9	1.6	2.3	100
ST142	Tunable Laser	1	External	1.5	-	2.3	4.06	50
ST143	Mixer/Detector	1	External	.4	-	1.5	.19	5
ST144	Laser Electronics	1	Internal	1	.5	.5	.25	10
ST283	Power Supply, Laser	1	External	1.58	1.17	1.5	2.77	100
ST277	Telescope, 24-inch	1	Internal	2	-	-	-	150

*Deploys 15 feet

Configurations. Not available.

Electrical/Data Requirements. EO-2 (XST011)

Equipment		Power (w)		Data	
Ref. No.	Name	Stby	Operate	Form	Rate
	Double-ended Absorption				
ST008	Data Recorder	25	250	D	-
ST042	Boom	-	20	-	-
ST136	Tunable Laser	2	10	-	-
ST138	IR Detector	-	10	D	80 KBPS
ST139	Cryogenics	-	10	-	-
ST141	C/D Console	-	20	-	-
ST277	Telescope				
ST283	Power Supply	-	20	-	-
	Heterodyne Radiometer				
ST008	Data Recorder	25	250	D	-
ST142	Tunable Laser	2	10	-	-
ST143	Mixer/Detector	-	10	D	80 KBPS
ST144	Laser Electronics	-	10	-	-
ST277	Telescope				
ST283	Power Supply	-	20	-	-

Pointing and Stability Requirements.

Shuttle Pointing Requirements & Final Instrument Pointing Capability

Equipment		Pointing & Stability*			
Ref. No.	Name	Accuracy (deg)	Duration (sec)	Stability (deg)	Stab. Rate (deg/sec)
ST136	Tunable Laser	2	2160	2	.5
ST138	IR Detector	2	2160	2	.5
ST142	Tunable Laser	1	120	1	.1

*Target Tracking

Field of View

IR detector
Instantaneous FOV: 1 degree
Total FOV: 2 degrees

Mission Operation. The experiment is to be operated from a polar orbit for global coverage. Any orbit, however, will provide meaningful data. Experiment is to be performed 2 times/day, 14 times/mission. There are approximately 10 viewing opportunities/day.

EVA Activity. None

Crew Function. Pointing and tracking is required for the double-ended system. To obtain complete tunability of the injection laser from 2 to 30 micrometers, a variety of injection lasers must be used. The procedure for changing lasers would involve a snap-in procedure for a trained technician. Minor alignment of system optics may be required.

Consumables

Magnetic tape: 10 lb, 0.2 ft^3
Film: None
Cryogenics: Helium or nitrogen, 20 lb, 0.3 ft^3

Environmental Requirements. EO-2 (XST011)

Operational Status	Temp (°K)	Rel. Hum. (%)	Cleanliness (Class)	Acoustics (dB)	Acceleration (g)
Operating					
Internal Equipment	295 ± 5	55 ± 25	300,000	60	.001
External Equipment					
Non-Operating					
Internal Equipment	295 ± 20	50 ± 45	300,000	145	9.0
External Equipment	283 ± 83		300,000	145	9.0

Development Status. A CO_2 laser heterodyne radiometer is currently being developed by AIL, a division of Cutler-Hammer for GSFC under Contract NAS5-23056. Scheduled completion date is November 1976.

EXPERIMENT EO-3 (XST012)

Multispectral Scanner for Coastal Zone Oceanography

Objective. The purpose of this experiment is to obtain narrow band spectral signatures of coastal zone features as a function of spatial resolution and field of view.

Description. This experiment consists of two solid-line scanners; one a low-resolution, wide field-of-view instrument; the other, a high-resolution narrow field-of-view instrument. Both instruments have an off-nadir pointing capability. The high-resolution instrument is used to sample selected areas of the field of view of the low-resolution instrument. Figure C-12 illustrates the scanning system. A block diagram of the multispectral scanner is shown in Figure C-13.

The experiment involves observations of predetermined coastal zone environmental features with various combinations of spectral wavelength, spatial resolution and field of view.

Physical Parameters. EO-3 (XST012)

Equipment		Qty	Location	Size (ft)			Vol (ft^3)	Wt (lb)
Ref.No.	Name			W/Dia	H	L		
ST008	Tape Recorder	1	Internal	1.6	.9	1.6	2.3	100
ST033	H. Res. Scanner	1	External	1.5	-	2.5	4.4	40
ST034	L. Res. Scanner	1	External	1.5	-	2.5	4.4	40
ST035	Data Processing Equip.	1	Internal	1	1	1	1	10
ST036	C/D Console	1	Internal	1.5	2	2	6	60

Configuration. Not available.

Electrical/Data Requirements. EO-3 (XST012)

Equipment		Power (w)		Data	
Ref. No.	Name	Stby	Operate	Form	Rate
ST008	Tape Recorder	25	250	D	-
ST033	H. Res. Scanner	15	15	D	10 MBPS
ST034	L. Res. Scanner	15	15	D	10 MBPS
ST035	Data Processing Equip.	10	10	D	-
ST036	C/D Console	120	120	Displays	-

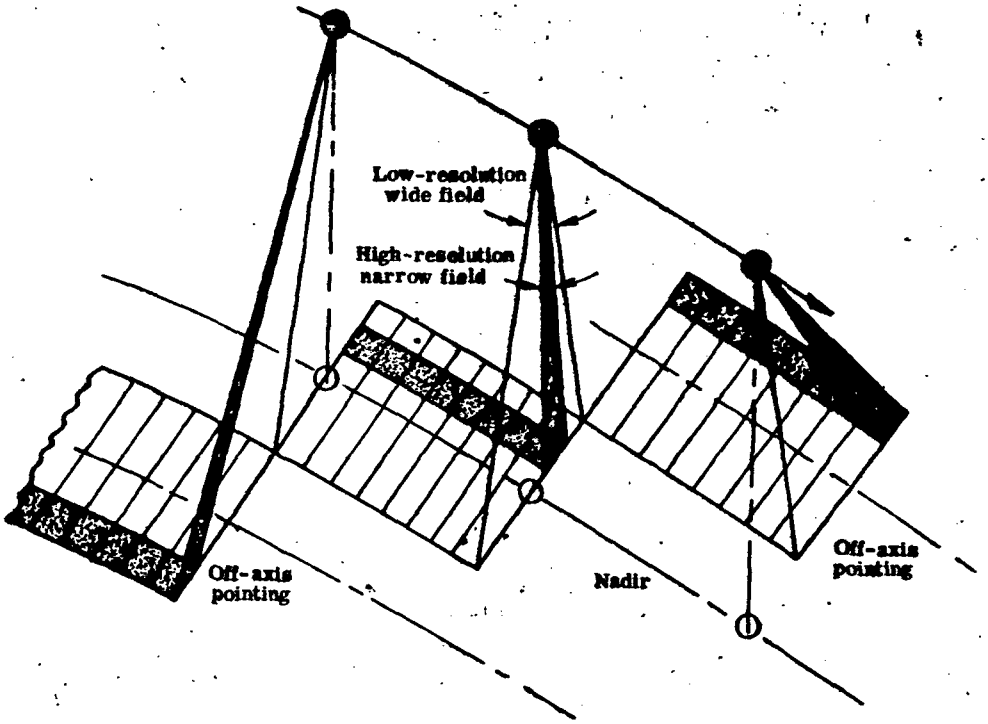


Figure C-12. Multispectral Imaging System for Coastal Zone Studies

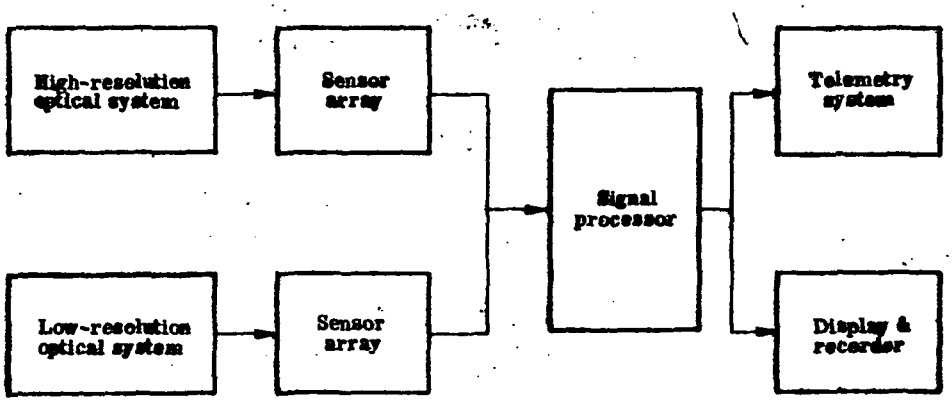


Figure C-13. Block Diagram of Multispectral Scanner for Coastal Zone Oceanography Experiment

The minimum acceptable data rate of 10 Mbps permits one 10-meter (32.8 feet) resolution channel and one 75-meter (246.1 feet) resolution channel to be obtained. It is desired, however, to make the observations simultaneously in at least three spectral bands. This would result in a maximum data rate of 30 Mbps.

Pointing and Stability. EO-3 (XST012)

Equipment		Pointing & Stability			
		Accuracy	Duration	Stability	Stab. Rate
Ref. No.	Name	(Deg)	(Sec)	(Deg)	(Deg/Sec)
Shuttle Pointing Req					
ST033	H. Res. Scanner	.5	1800	.5	.1
ST034	L. Res. Scanner	.5	1800	.5	.1
Final Instrument Pointing Cap					
ST033	H. Res. Scanner	.1	300	.1	.02
ST034	L. Res. Scanner	.1	300	.1	.02

An earth pointing capability of 0.3 to 0.6 degree and attitude determination of 0.01 to 0.03 degree are desired.

Field of View

Total FOV: High-resolution scanner, 2.9 degrees
Low-resolution scanner: 28 degrees

Mission Operation. It is preferred that the experiment be performed from an orbit such as 64 degrees retrograde that is tuned to the coastal zones of interest. Any orbit, however, provides useful data. The experiment is to be performed 3 times/day, 18 times/mission. The observations are to be of earth coastal regions under favorable lighting conditions. The frequency duration of observation depends upon the orbital parameters.

EVA Activity. None.

Crew Function. The experiment is highly automated. Crew function is limited to initiation of experiment instrument calibration and monitoring instrument performance.

Consumables

Magnetic tape: 50 lb, 1 ft^3
Cryogenics: None

Environmental Requirements. EO-3 (XST012)

Operational Status	Temp (°K)	Rel. Hum. (%)	Cleanliness (Class)	Acoustics (dB)	Acceleration (g)
Operating					
Internal Equip External Equip	295 ± 5	55 ± 25	300,000	60	.001
Non-Operating					
Internal Equip	295 ± 20	50 ± 45	300,000	145	9.0
External Equipment	283 ± 83		300,000	145	9.0

Development Status. The development and qualification of the basic instrument system is contingent upon the definition of a coastal zone oceanography experiment.

EXPERIMENT EO-4 (XST002)

Microwave Radiometer Measurements

Objective. The purpose of this experiment is to (1) develop and test new microwave components and techniques, (2) make day/night measurements of ocean temperature and sea state with microwave radiometers under varying meteorological conditions, and (3) measure radio-frequency radiation from galactic sources.

Description. This experiment employs a passive receiver to measure the emission from radiators such as the ocean at a frequency selected to minimize the effects of the ionosphere, clouds, atmosphere, and background noise. Minimum attenuation due to atmosphere, ionosphere and clouds exists in the frequency range of 30 MHz to 10 GHz. Within this region, thermal emissions from the ocean can be detected both day and night under adverse weather conditions. Within the aforementioned frequency band, frequencies can be monitored between 1 GHz and 10 GHz with a minimum of background noise, thereby permitting high measurement accuracy.

The radiometer provides an output signal level that is proportional to the temperature of the ocean within the antenna footprint. This output signal is a function of the received power. The source temperature change can be derived from the change in received power according to the relationship

$$P = \text{Delta-TKB}$$

where Delta-P is the change in received power, Delta-T is the change in source temperature, K is Boltzman's constant, and B is the receiver bandwidth.

It is important to constrain the power received at the radiometer to the energy emitted from the ocean surface. In addition, the antenna beam efficiency must be carefully designed and controlled. The antenna for this experiment is a corrugated horn antenna designed to operate between 1 GHz and 8 GHz, and have a beam efficiency of 98 percent with ohmic loss less than 0.05 dB. The antenna configuration is depicted in Figure C-14. The spatial resolution of the system is a function of the aperture size as shown in Figure C-15. The antenna will be stowed in the Shuttle bay during delivery into orbit and deployed for experiment operation.

After deploying the antenna, feed and frequency selection, equipment turn-on, and calibration from both on-board and ground installation sources, data runs will be performed in an earth-looking orientation while flying over ocean areas. During these observation intervals, on-board monitoring and periodic calibrations will be performed and data recorded. Simultaneous photographic coverage in the optical and infrared spectrum will be made for post-flight comparison. Spacelab position and stability, antenna look-angles, polarization, frequency, and antenna temperature are to be recorded during data runs.

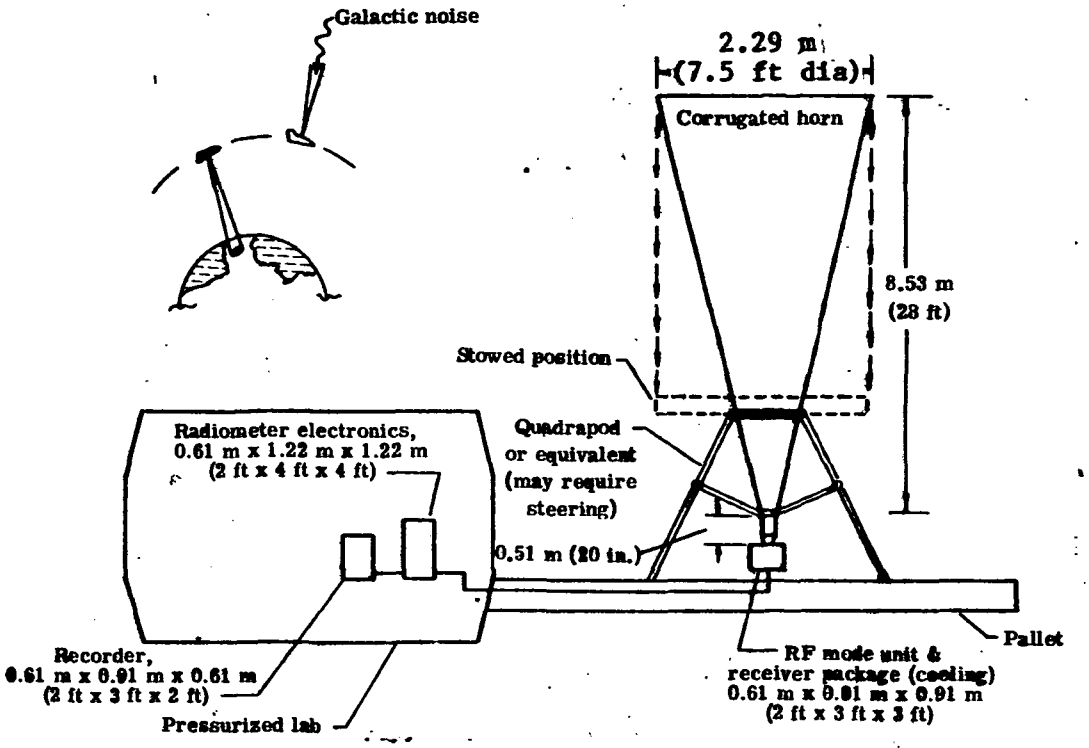


Figure C-14. Radiometer Concept for ATL

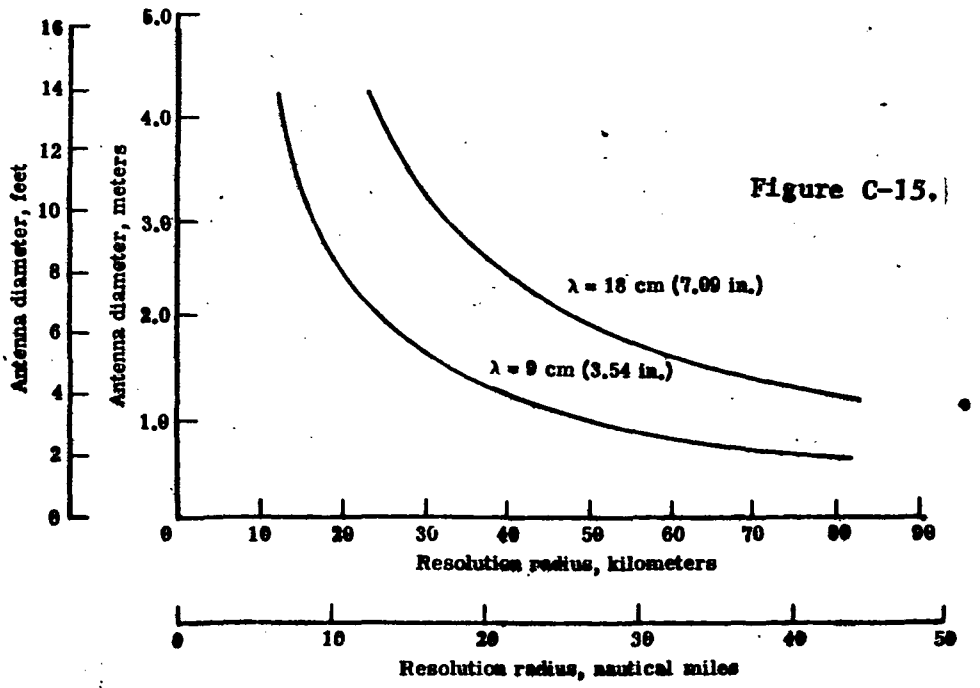


Figure C-15.

Maximum resolution as a function of antenna radius for nadir-looking microwave radiometer at 556 km (300 n. mi.) orbital altitude. λ is wavelength.

During those portions of the orbit when the Spacelab is over terrain, the antenna is to be pointed toward space to make calactic noise measurements to provide data on background noise temperature.

A block diagram of this experiment is shown in Figure C-16.

Physical Parameters. EO-4 (XST002)

Equipment Ref.No.	Name	Qty	Location	Size (ft) W/Dia	H	L	Vol (ft^3)	Wt (lb)
ST007	Oscilloscope	1	Internal	1.6	.6	1.5	1.44	29
ST008	Digital Recorder	1	Internal	1.6	.9	1.6	2.3	100
ST013	Corrugated Horn Antenna	1	External	12.5*	-	6.5*	798*	300
ST014	Radiometer	1	External	2	3	3	18	40
ST015	Strip Chart Recorder	1	Internal	1.5	1	1.6	2.16	100
ST016	Signal Generator	1	Internal	1.58	.58	1.5	1.38	20
ST017	Spectrum Analyzer	1	Internal	1.58	.58	1.5	1.38	30
ST018	Radiometer Electronics	1	Internal	2	4	3	24	50
ST019	Still Camera	1	Internal	.5	.5	.5	.125	5
ST020	C/D Console	1	Internal	1.6	1	1	1.6	20

*Stowed dimensions. Antenna deploys to be 12.5 dia x 25 feet.

The corrugated horn antenna is folded and stowed during Shuttle flight to and from orbit.

Vehicle maneuvering and antenna steering and mounting on the pallet within the Shuttle bay will require special emphasis to ensure proper viewing of target areas.

Configuration. Not available.

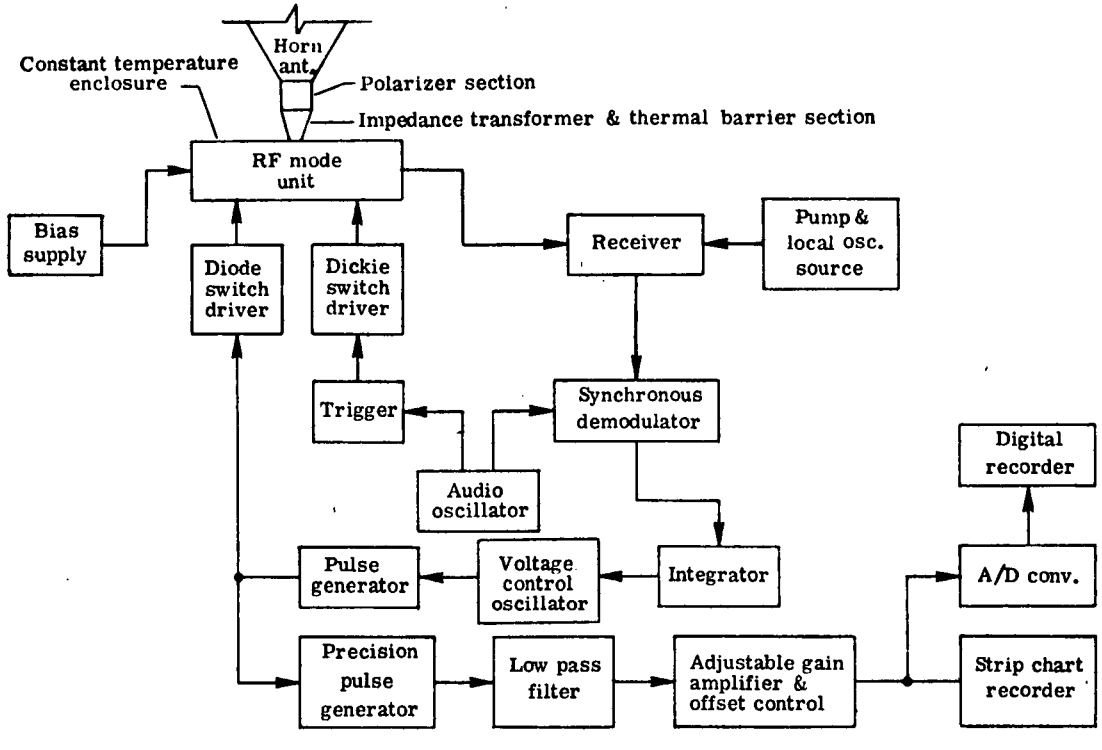


Figure C-16. Block Diagram of Microwave Radiometer Measurements Experiment

Electrical/Data Requirements. EO-4 (XST002)

Equipment		Power (w)		Data	
Ref. No.	Name	Stby	Operate	Form	Rate
ST007	Oscilloscope	30	92	CRT	-
ST008	Digital Recorder	25	250	D	-
ST013	Corrugated Horn Antenna	-	-	A	-
ST014	Radiometer	20	20	A	45K
ST015	Strip Chart Recorder	25	250	Display	-
ST016	Signal Generator	30	30	A	-
ST017	Spectrum Analyzer	50	50	A	-
ST018	Radiometer Electronics	20	20		-
ST019	Still Camera	0	5	Film	
ST020	C/D Console	10	10	-	-

Pointing and Stability Requirements. The pointing and stability requirements for the corrugated horn antenna are as follows:

Target	Area Requirement	Accuracy (Deg)	Duration (Sec)	Stability (Deg)	Stab. Rate (Deg/Sec)
Galactic	Shuttle Pointing	.5	1800	.5	.1
	Mount Pointing*	.2	1800	.2	.1
	Final Inst. Pointing	.2	1800	.2	.1
Earth Surface	Shuttle Pointing	.5	600	.2	.2
	Mount Pointing*	.2	600	.2	.1
	Final Inst. Pointing	.2	600	.2	.1

*Accuracy required at inner gimbal.

Field of View

Antenna instantaneous FOV: 0.3 degree
Antenna total FOV: 30 degrees (cross-track)

Mission Operation. The experiment is to be conducted from an altitude of 100 to 300 nmi. Earth-looking measurements are to be made over ocean areas and space-looking measurements are to be made over land areas. Antenna rotation during data taking is to constrain to less than 0.2 deg/sec. Galactic and earth surface observations are to be performed 16 times per day each. Total number of galactic observations per mission is 16. Total number of earth surface observations per mission is 64.

EVA Activity. None

Crew Functions. Initiate and monitor antenna deployment; set up and check out equipment; test and calibrate radiometer; direct the antenna and operate the equipment during data-taking intervals; monitor signals and observe target areas; photograph targets; monitor and operate recording equipment; maintain voice contact and coordinate with ground operations; and secure equipment for reentry and return flight.

Consumables. Film: TBD
Magnetic tape: TBD
Strip chart: TBD
Cryogenics: None

Environmental Requirements. EO-4 (XST002)

Operational Status	Temp (°K)	Rel. Hum. (%)	Cleanliness (Class)	Acoustics (dB)	Acceleration (g)
Operating					
Internal Equip	295 ± 5	55 ± 25	300,000	60	.001
External Equip					
Non-Operating					
Internal Equip	295 ± 20	50 ± 45	300,000	145	9.0
External Equip	283 ± 83		300,000	145	9.0

Development Status. A radiometer and antenna are currently under development by LaRC, and ground-based experiments are in progress to develop a technique for extracting sea state from radiometric measurements. Aircraft system flight tests are planned for CY 1974. Results from this effort will be used to design flight hardware for flight on the Shuttle.

EXPERIMENT EO-5 (XST003)

Precision Laser Ranging and Altimetry

Objective. The purpose of this experiment is to (1) determine the utility, limitations, and accuracy of a mode-locked laser ranging system to measure range, line-of-sight angles and range rate; (2) evaluate the utility of on-board laser ranging to measure range to within ±3 cm over Shuttle-to-ground distances; (3) isolate problems that may be associated with the use of laser ranging in the earth-space environment; and (4) determine optimal engineering parameters under various modes of operation and operating conditions.

Description. Unlike microwave radars, optical systems for laser ranging maintain high isolation between the transmitter and the receiver. This allows for either continuous wave or pulse operations plus the measurement capability to essentially zero range. Short pulse operation and narrow beamwidths can be combined to provide high range and angle resolution. For applications such as remote satellite stationkeeping from a manned vehicle, or rendezvous between manned vehicles, laser ranging techniques appear ideally suited. In applications requiring transmission through the atmosphere, such as altimetry, where absorption and scattering occur, special attention must be given to frequency selection and the monitoring of meteorological conditions. In keeping with these considerations, this experiment will be conducted with cooperative targets. To minimize search time, an auxiliary tracking instrument has been included.

Current ground-to-satellite measurements are made with an uncertainty of between 20 and 30 cm. Ranging with an accuracy of ±3 cm would permit more accurate measurement of the spatial variations of the earth's gravitational field, the measurement of tectonic motions of the earth, and improvement of geodimeter transverse surveys. The availability of accurate ephemeris data would improve satellite position predictions, thereby impacting future satellite systems. This experiment will provide the necessary flight development testing of a laser ranging system capable of measuring satellite distances to within ±3 cm.

In this experiment, range is measured as a function of transmission time. A laser pulse is emitted, reflected from a retroreflector, and returned to the receiver. Transmission time is accurately measured to effect range measurements to within ±3 cm.

Two separate modes of operation are considered in this experiment: (1) laser radar operation between the Shuttle and a target satellite and/or

aircraft, and (2) laser radar operation as a Shuttle-to-earth surface-ranging altimeter. A different output energy level is required for each operation mode.

In the Shuttle-to-satellite or aircraft mode, measurements will be made with a cooperative target at various ranges up to 300 nmi. Tests will be scheduled to include different background illumination conditions to aid in evaluating target acquisition and tracking under varying noise conditions.

The Shuttle-to-satellite measurements will be addressed to determine target acquisition and lock-on capability, probability of detection, system accuracy, and false-alarm rate. To evaluate target acquisition and lock-on, tests will be conducted using diminished search volume techniques having known relative ephemeris. This mode of operation, however, is considered of secondary importance.

The Shuttle-to-earth measurements are to receive primary emphasis. The Shuttle will carry a mode-locked laser transmitting and receiving system, and ranging measurements will be made to known ground areas and retroreflectors. Absorption, scattering, and background reflectivity of terrestrial features require additional monitoring to assess the overall instrument performance. For these reasons, meteorological conditions and accurate footprint measurements and calculations will be required. Shuttle-to-earth measurements will be made to evaluate the accuracy of range data obtained and to determine the effect of cloud cover, weather patterns, climatic conditions, and geography on instrument performance.

To aid in this evaluation, consideration is being given to the use of a high-resolution microwave altimeter for making simultaneous range measurements. Photographic recording of cloud cover is to be made and ground-truth data from known land surveys will be used to select target locations.

A simplified block diagram of the Shuttle-to-earth transmitter-receiver system is shown in Figure C-17; a breakdown diagram showing the optical and electrical data flow paths is shown in Figure C-18; and a preliminary instrument configuration is illustrated in Figure C-19.

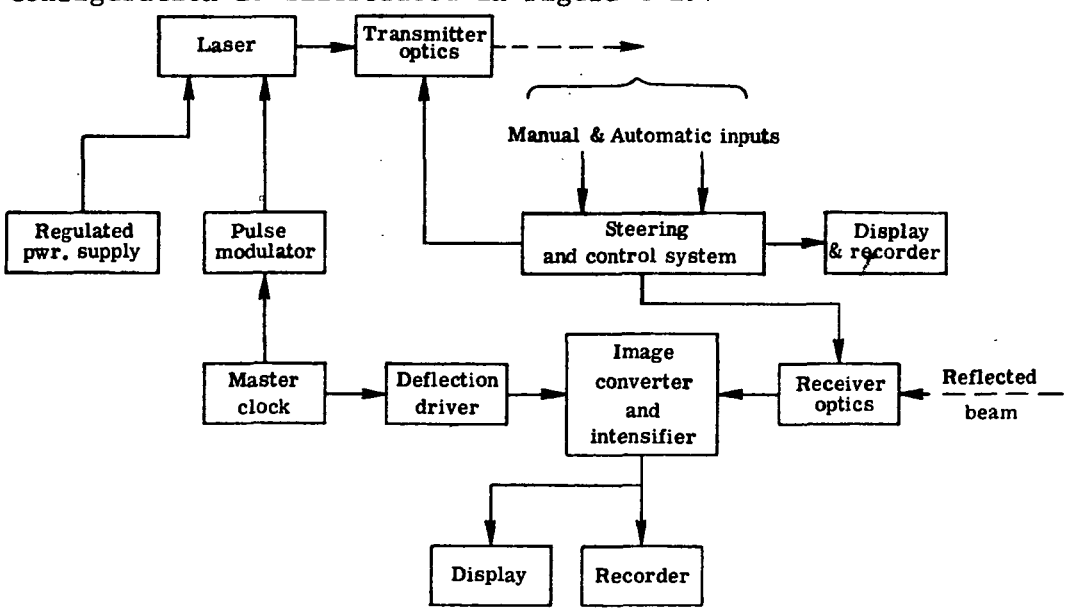


Figure C-17. Block Diagram of Mode-Locked Laser Ranging Instrument

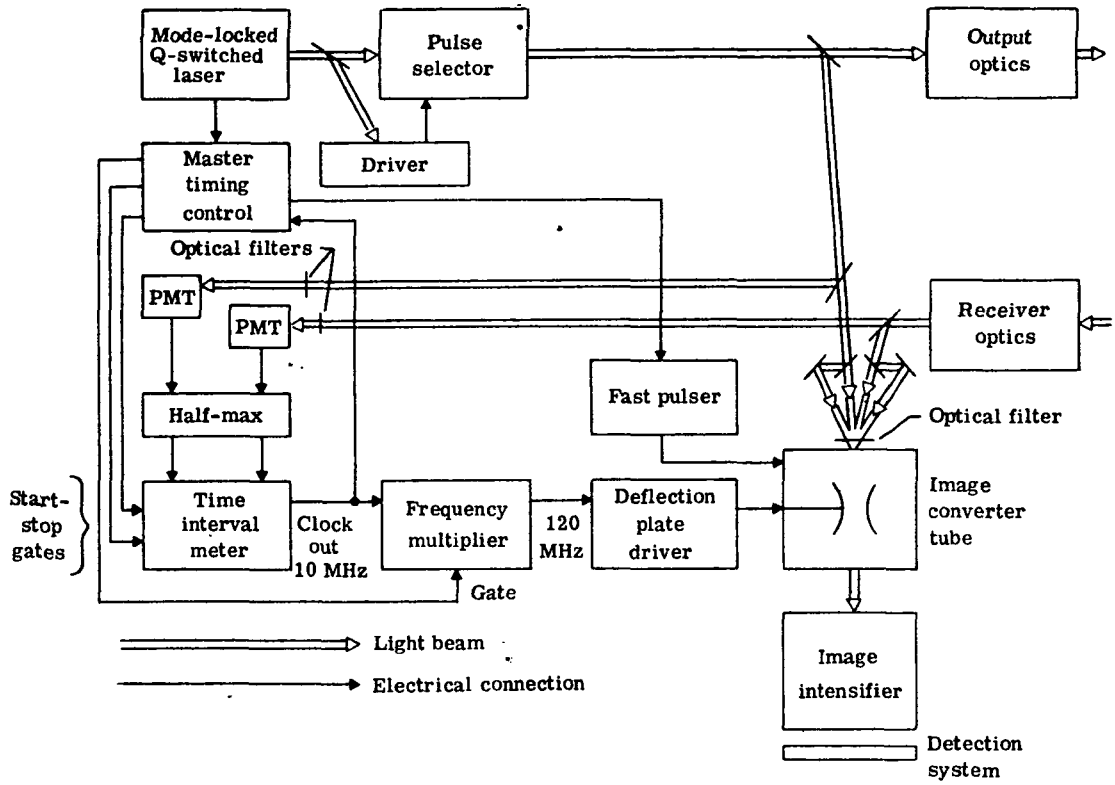


Figure C-18. Flow Schematic of Mode-Locked Laser Signal

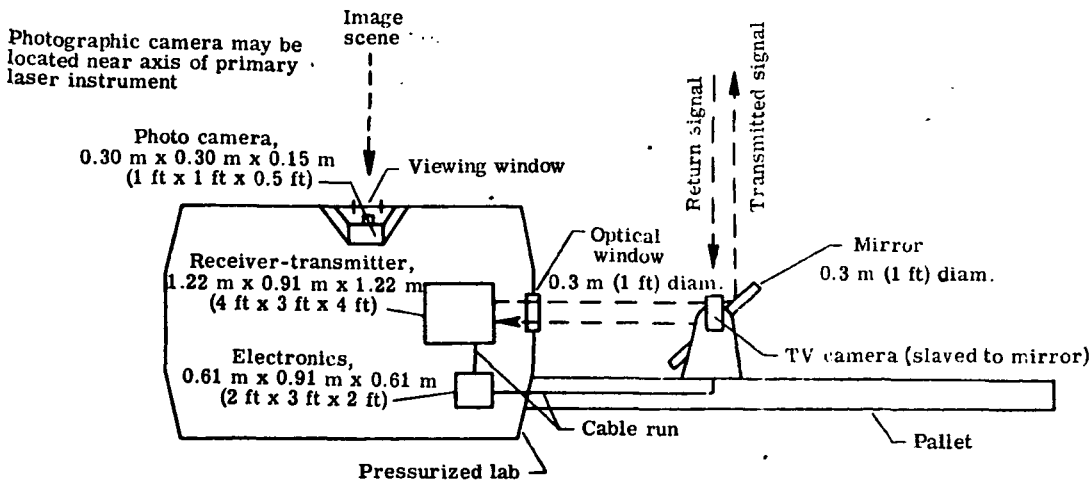


Figure C-19. Laser Ranging Experiment

Physical Parameters. EO-5 (XST003)

Equipment				Size (ft)			Volume	Weight
Ref. No.	Name	Qty	Locations	W/dia	H	L	(ft^3)	(lb)
ST025	TV Camera	1	External	0.25	0.5	0.67	0.08	5
ST054	Still Camera	1	Internal	0.25	0.5	0.5	0.063	50
ST118	Laser	1	Internal	4.0	4.0	3.0	48.0	260
ST119	Retroreflector	1	External	1.0	-	1.66	1.3	10
ST120	Track Instrument	1	External	0.5	1.0	1.0	0.5	20
ST122	Electronics	1	Internal	2.0	2.0	3.0	12.0	50

Configuration Not available.

Electrical/Data Requirements. EO-5 (XST003)

Equipment		Power (Watts)		Data	
Ref. No.	Name	Standby	Operate	Form	Rate
ST025	TV Camera	-	50	Display	-
ST054	Still Camera	-	50	Film	-
ST118	Laser	-	600	-	-
ST119	Retroreflector	-	-	-	-
ST120	Track Instrument	-	15	D	1 kbps
ST122	Electronics	-	100	-	-

Pointing and Stability Requirements. EO-5 (XST003)

Equipment		Pointing Accuracy (degrees)	Duration (seconds)	Stability (degrees)	Stability Rate (deg/sec)
Ref. No.	Name				
SHUTTLE POINTING REQUIREMENTS					
ST118	Laser**	0.5	1800	0.5	0.1
ST120	Tracking Instrument	0.5	1800	0.5	0.1
MOUNT POINTING REQUIREMENT*					
ST118	Laser**	0.01	180	0.01	0.1
ST120	Tracking Instrument	0.1	180	0.1	0.1
FINAL INSTRUMENT POINTING CAPABILITY					
ST118	Laser**	0.01	180	0.01	0.1
ST120	Tracking Instrument	0.01	180	0.1	0.1

*Accuracy required at inner gimbal.
**Target tracking.

Field of View

Track instrument
Instantaneous FOV: 1 degree
Total FOV: 10 degrees

A clear, uncontaminated, optical field of view is required during data-taking and the optical system must remain clear during total mission time.

Mission Operation. Experiment to be conducted from a 100 to 300 nmi altitude with low earth orbit ground track over known target areas. Coordination with aircraft or other satellites is required.

Target lock-on and tracking will require special equipment, including target source illumination, without producing undesirable background noise at laser frequencies. Further analysis is required to select targets.

EVA Activity. None

Crew Function. Test, calibrate and maintain equipment; observe and select targets; monitor data-taking; coordinate with targets, ground-track, and other experiments; check optical system performance; secure recorded data; and shut down equipment and secure for reentry and landing.

Consumables

Film: 10 lb, 0.2 ft^3
Magnetic tape: 10 lb, 0.2 ft^3
Cryogenics: None

Environmental Requirements. EO-5 (XST003)

Operational Status	Temp. (°K)	Relative Humidity (Percent)	Cleanliness (Class)	Acoustics (dB)	Acceleration (g)
OPERATING					
Internal Equipment	295 ± 5	55 ± 25	300,000	60	0.001
External Equipment					
NON-OPERATING					
Internal Equipment	295 ± 20	50 ± 45	300,000	145	9.0
External Equipment	283 ± 83		300,000	145	9.0

Development Status. Development of the basic laser instrument for use in this experiment will require a 16-man-year effort over a 4-year period.

EXPERIMENT EO-6 (XST005)

Microwave Altimetry

Objective. The purpose of this experiment is to determine the utility, limitations and accuracy of a microwave altimeter for all-weather use in measuring relative earth surface height variations; to determine the accuracy of measuring scattering cross-section density for different surface features and compositions falling within the altimeter target area; and to investigate the simultaneous use of the altimeter as a passive radiometer operating at a different frequency band or between radar returns.

Description. This experiment will be used to make altitude measurements to the earth's surface as it passes directly beneath the Shuttle. These measurements are to be made during successive passes over known ground tracks within the continental U.S., over oceans, and other selected target areas as appropriate. The altimeter will operate at microwave frequencies, and measurements will be correlated with meteorological conditions. Electronically steerable antenna beam pointing will be investigated to assess its potential and accuracy for maintaining ground track with related vehicle stability requirements. Passive measurements will be made at different frequencies or between active return from the radar using the receiver and antennas as a radiometer to measure relative changes in emissivity of areas passing beneath the Shuttle. A known ground track segment will be identified as a reference target to aid in post-analysis assessment of instrument accuracy.

The instrument employs three or four modes of operation--synthetic aperture altimeter (with and without electronic steering) and radiometer measurements (double frequency and/or between returns). Signal monitoring and display are required. Data are to be recorded on magnetic tape. Altitude measurements will be used in conjunction with other experiments to perform system error analyses.

A block diagram is shown in Figure C-20, and the equipment configuration is illustrated in Figures C-21 and C-22.

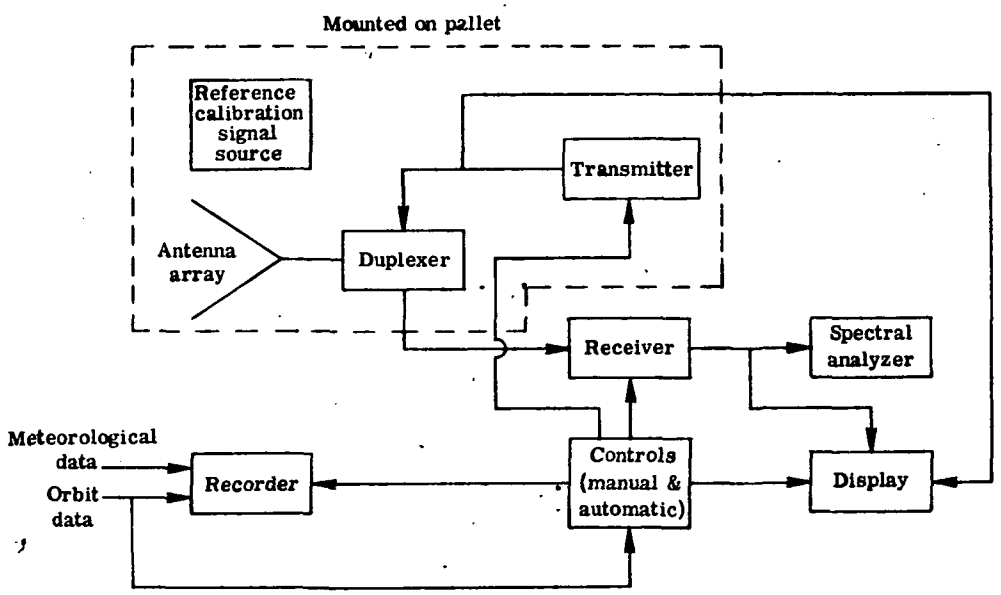


Figure C-20. Block Diagram of Microwave Altimeter Experiment

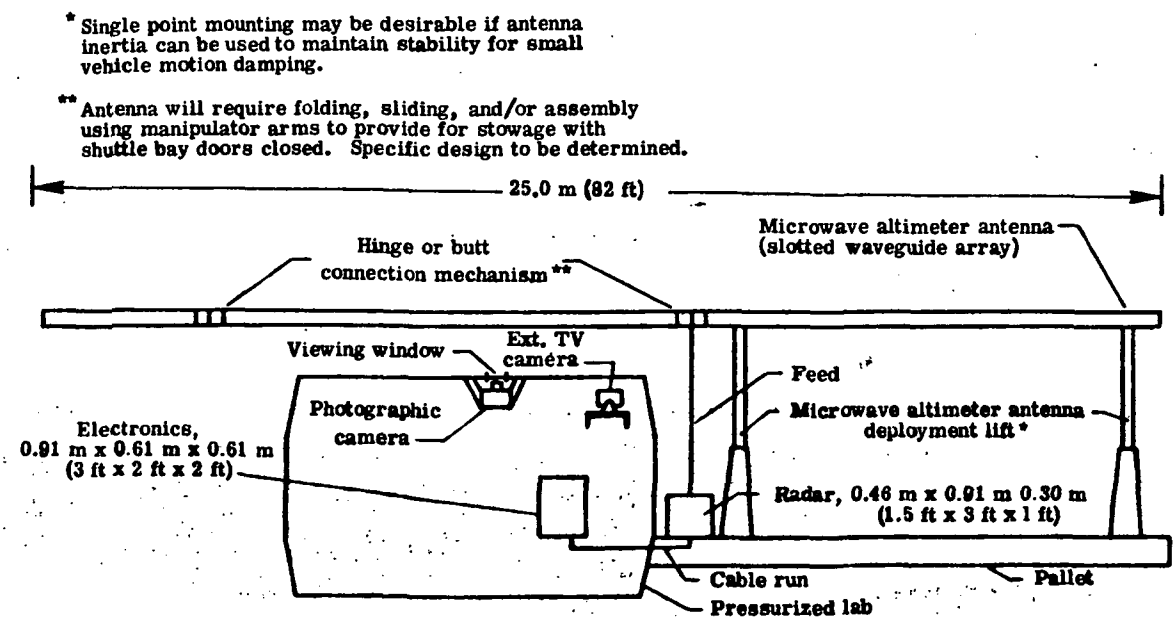


Figure C-21. Microwave Altimeter Experiment Equipment

Physical Parameters. EO-6 (XST005)

Equipment		Qty	Location	Size (ft)			Vol.	Weight
Ref No.	Name			W/dia	H	L	(ft^3)	(lb)
ST007	Oscilloscope	1	Internal	1.6	0.6	1.5	1.44	32
ST017	Spectrum analyzer	1	Internal	0.8	0.8	0.8	0.51	15
ST019	Still camera	1	Internal	0.5	0.5	0.5	0.125	5
ST025	TV camera	1	External	0.25	0.5	0.67	0.08	5
ST026	TV monitor	1	Internal	1.0	1.0	1.5	1.5	25
ST123	Microwave altimeter electronics	1	Internal	2.0	3.0	2.0	12.0	240
ST124	Radar	1	External	1.5	3.0	1.0	4.5	90
ST125	Slotted waveguide antenna**	1	External	6.5	0.5	82.0	266.5	3000
ST126	C&D console	1	Internal	2.0	3.0	2.5	15.0	60
ST273	Optical recorder	1	Internal	5.0	2.0	2.0	20.0	100
ST274	Antenna mount*	2	External	4.0	-	5.0	62.9	

*Extends to 10 feet with 0.75 foot telescope column
**Retracts to 30 feet length, 1.5 feet thick

Configuration. See Figures C-21 and C-22.

Electrical/Data Requirements. EO-6 (XST005)

Equipment		Power (watts)		Data	
Ref. No.	Name	Standby	Operate	Form	Rate
ST007	Oscilloscope	30	92	Display	-
ST017	Spectrum analyzer	50	50	A	
ST019	Still camera	0	5	Film	-
ST025	TV camera	-	50	Display	-
ST026	TV monitor	-	100	-	-
ST123	Altimeter electronics	-	200	-	-
ST124	Radar	-	400	D	30 kbps
ST125	Waveguide antenna	-	-	-	-
ST126	C/D console	-	50	-	-
ST273	Optical recorder	25	250	Film	-
ST274	Antenna mount				

Pointing and Stability Requirements. Antenna requirements are as follows.

Item	Accuracy (deg)	Duration (sec)	Stability (deg)	Stability Rate (deg/sec)
Shuttle pointing requirement	0.5	1800	0.5	0.1
Final instrument pointing capab	0.05	180	0.05	0.05

Field of View. This experiment involves data-taking over known ground elevation tracks and requires an unobstructed RF field of view. Thermal stability of the antenna during data runs is required and antenna development will require special mechanical design of the segmented antenna elements to ensure precision alignment to maintain close physical tolerances during data runs. Tolerances are to be determined from ground-based testing.

Mission Operation. Experiment to be conducted from a 100 to 300 nmi altitude with ground track over known ground target areas. Experiment is to be performed 5 times/day, 25 times/mission. There are approximately 18 viewing opportunities per day.

EVA Activity. None

Crew Functions. Deploy and set up equipment; turn ON, test, and calibrate equipment; select operation mode; control and monitor equipment during data-taking; photograph target area; monitor and operate data recording equipment; coordinate measurement-taking with ground sites and other experiments; and secure equipment for reentry and return flight.

Consumables

Film: 5 lb, 0.1 ft^3
Magnetic tape: 10 lb, 0.2 ft^3
Cryogenics: None

Environmental Requirements. EO-6 (XST005)

Operational Status	Temperature (°K)	Relative Humidity (%)	Cleanliness (Class)	Acoustics (dB)	Acceleration (g)
OPERATING					
Internal equip.	295 ± 5	55 ± 25	300,000	60	0.001
External equip.					
NON-OPERATING					
Internal equip.	295 ± 20	50 ± 45	300,000	145	9.0
External equip.	283 ± 83		300,000	145	9.0

Development Status. Basic radar techniques have been developed and unique equipment exists that can be modified to investigate the design concepts required for this experiment. Analytical studies and ground-based testing are required to establish a final design and development schedule.

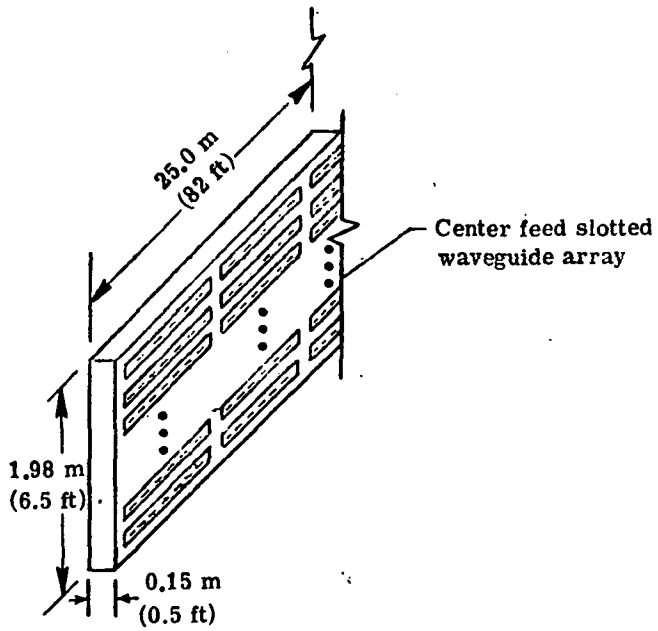


Figure C-22. Microwave Altimeter Antenna

EXPERIMENT EO-7 (XST006)

Search and Rescue Aids

Objective. The purpose of this experiment is to determine via *in situ* measurements the utility, limitations, and accuracy of detecting, identifying and positioning earth-located passive targets on vehicles in emergency situations using an orbiting side-looking radar system for detection and location determination; develop, test, and demonstrate RF passive targets that are suitable for installation on a number of different vehicle types; demonstrate the utility of having surface image data simultaneously provided with position data to assist and structure rescue operations with minimum delay; determine and demonstrate the capacity of an orbiting radar system to maintain tracking data on classes of mobile platforms equipped with passive targets; examine the relative system advantages and disadvantages of passive (reflector) and active (transponder) targets for use in search operations; and explore passive techniques for determining geographical position.

Description. The Shuttle-based side-looking radar will be used to image on a search and surveillance area as successive flight passes are made over the U.S. and ocean areas. Within these target areas, known fixed and moving targets will be equipped with an appropriate RF reflector and/or transponder that can be individually manipulated to provide positive identification. The testing will concentrate in three areas: (1) reflector target and transponder test and evaluation, (2) position and accuracy determination, and (3) surveillance of moving targets.

Early experimental activity will focus on exploring techniques for detecting and identifying specific targets within a field of approximately 10 meters by 10 meters. Reflectors will be positioned at appropriate ground locations to determine signal detection and separation capability under a variety of terrain and weather conditions for reflectors of varying sizes, configurations and materials. Single- and multiple-reflector techniques will be examined by using both rigid and erectable reflector devices having fixed and variable reflection characteristics.

After basic reflector performance measurements, detection techniques will be examined to measure ability to use these reflectors to aid establishing specific rescue operations. Data and voice communications will be used to coordinate testing. Image analysis will be made to establish usefulness of prescribing optimum rescue routes, vehicles and survival support action needed based on the accompanying terrain visibility. Tests will be performed in remote and semi-populated areas under a variety of day-night and meteorological conditions. Target position will be determined relative to both orbital position and a ground-established grid network consisting of natural and man-made highly visible targets having known reflective characteristics. The grid reflector network will serve as a primary measurement tool and post-analysis, based on orbital position, will be performed as a check on overall system accuracy. This phase of the experiment will be coordinated with landmark tracking to provide a ground truth verification for the autonomous navigation experiment and to measure geographical position on a global scale.

After completion of the fixed-target phase, experiment operation will continue with the surveillance of moving targets. Target reflectors will be utilized on aircraft, ships and small craft, and terrestrial vehicles, on a scheduled basis over selected tracks within view of the Shuttle-mounted side-looking radar.

A simplified block diagram of the side-looking radar system is shown in Figure C-23, and the configuration is illustrated in Figure C-24.

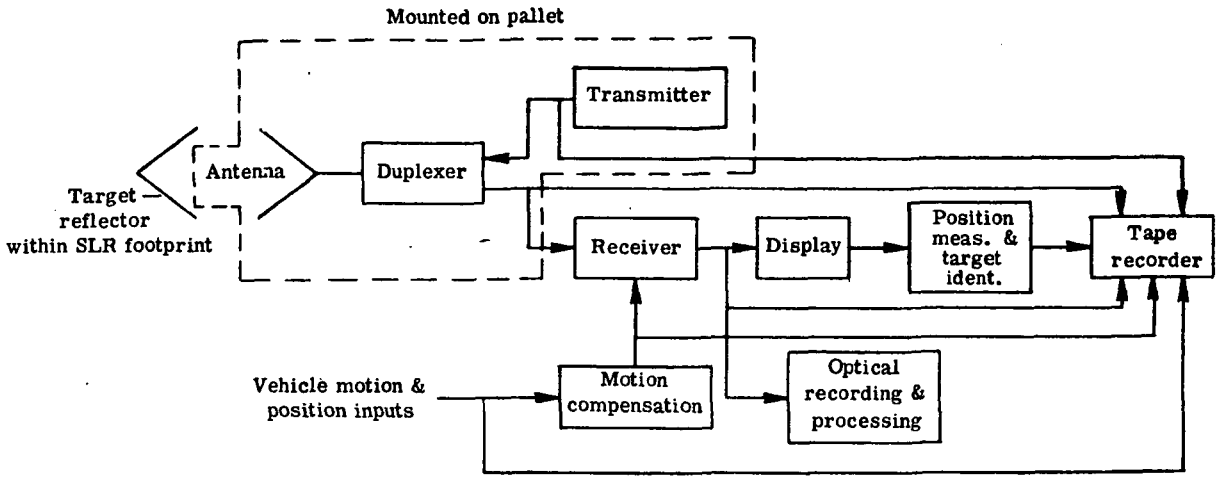


Figure C-23. Block Diagram of Side-Looking Radar for Search and Rescue Aids Experiment

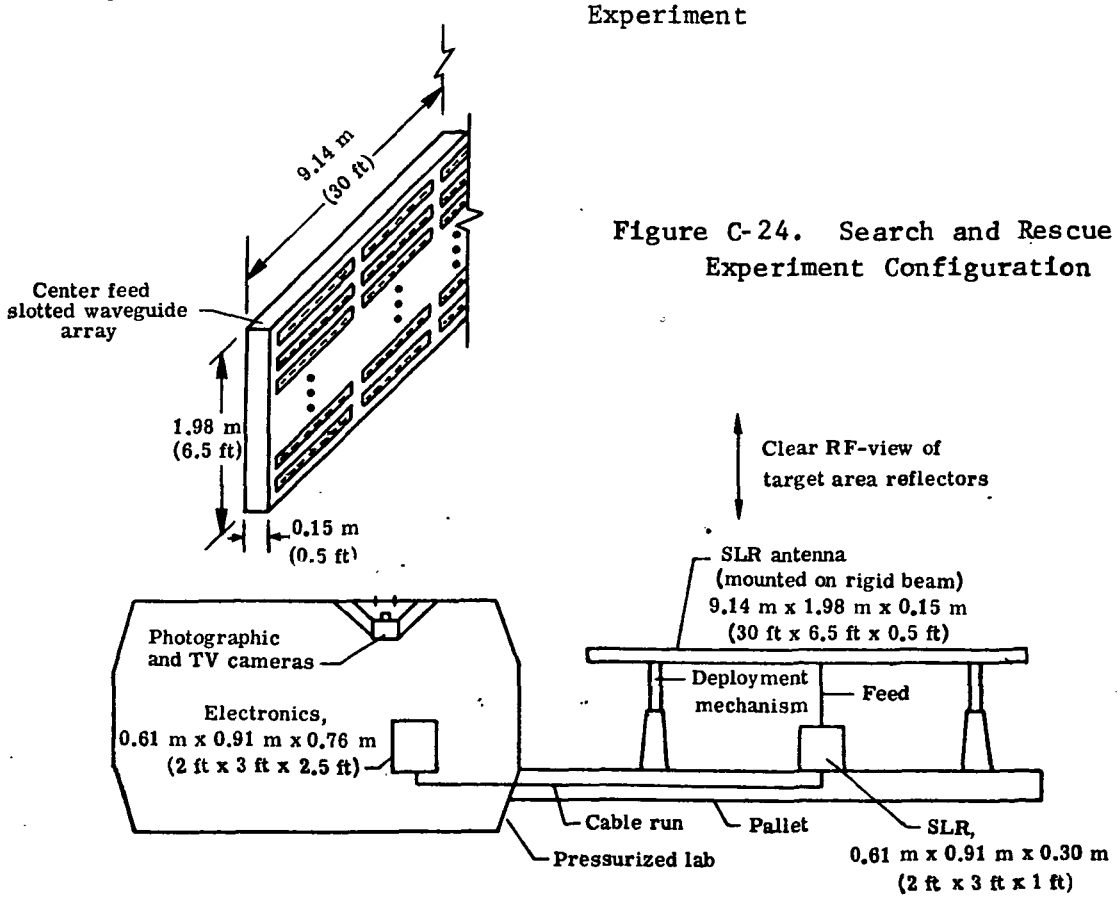


Figure C-24. Search and Rescue Aids Experiment Configuration

Physical Parameters. EO-7 (XST006)

Equipment		Qty	Location	Size (ft)			Vol. (ft^3)	Weight (lb)
Ref No.	Name			W/dia	H	L		
ST007	Oscilloscope	1	Internal	1.6	0.6	1.5	1.44	29
ST019	Still camera	1	External	0.5	0.5	0.5	0.125	10
ST025	TV camera	1	External	0.25	0.5	0.67	0.08	5
ST154	Side-looking radar electronics ***	1	External	2.0	3.0	2.5	15.0	600
ST155	Antenna***	1	External	6.5	0.5	30.0	97.5	1000
ST156	Freq. meter	1	Internal	1.0	1.0	1.0	1.0	30
ST157	C/D console	1	Internal	2.0	3.0	2.5	15.0	60
ST273	Optical recorder	1	Internal	5.0	2.0	2.0	20.0	100
ST274	Antenna mount**	1	External	4.0	-	5.0	62,9	*
ST286	Electronics	1	Internal	1.0	2.0	3.0	6.0	200

*Included in antenna weight
**Extends to 10 feet with 0.75 foot telescope column
***Same as XST008, Imaging Radar

Configuration. See Figure C-24

Electrical/Data Requirements. EO-7 (XST006)

Equipment		Power (watts)		Data	
Ref. No.	Name	Standby	Operate	Form	Rate
ST007	Oscilloscope	30	92	Display	-
ST019	Still camera		5	Film	-
ST025	TV camera	-	50	D	-
ST154	Radar electronics	-	900	-	-
ST155	Antenna	-	-	-	-
ST156	Frequency meter	-	10	-	-
ST157	C/D console	-	20	-	-
ST273	Optical recorder	25	250	D	-
ST274	Antenna mount	-	-	-	-
ST286	Electronics	-	-	-	-

Pointing and Stability Requirements. Antenna requirements are as follows:

Area	Accuracy (deg)	Duration (sec)	Stability (deg)	Stability Rate (deg/sec)
Shuttle pointing requirement	0.5	1800	0.5	0.1
Final instrument pointing capability	0.001	180	0.001	0.001

Field of View. Antenna pointing requires depression angles of from 45 to 60 degrees for side-looking view at target area. This can be achieved by roll maneuver of Shuttle or by antenna steering. Use of Shuttle roll maneuver will simplify hardware design, but constrain simultaneous operation of other experiments. Further analysis will be conducted to resolve issue.

Mission Operation. Experiment is to be operated over known target areas at an altitude of 100 to 300 nmi and at inclination of 30 to 90 degrees. Experiment is to be performed simultaneously with XST008, Imaging Radar Experiment. There are to be 5 observations/day, 25 per mission.

EVA Activity. None

Crew Functions. Set up and turn on equipment; coordinate with ground targets, communication center, and other on-board experiments; survey image data to extract target location measurements; operate and secure data storage; and secure equipment for return flight.

Consumables

Film: 5 lb, 0.1 ft^3
Magnetic tape: 10 lb, 0.2 ft^3
Cryogenics: None

Environmental Requirements. EO-7 (XST006)

Operational Status	Temperature (°K)	Relative Humidity (%)	Cleanliness (Class)	Acoustics (dB)	Acceleration (g)
OPERATING					
Internal Equip.	295 ± 5	55 ± 25	300,000	60	0.001
External Equip.					
NON-OPERATING					
Internal Equip.	295 ± 20	50 ± 45	300,000	145	9.0
External Equip.	283 ± 83		300,000	145	9.0

Development Status. Radar hardware exists and has been flown on aircraft. This equipment can be used for early ground-based measurements. Analytical work is needed to define system parameters, to design an orbital system, to select target areas, and to design and develop RF reflectors for the specific experiment.

EXPERIMENT EO-8 (XST008)

Imaging Radar

Objective. The purpose of this experiment is to determine the utility, accuracy and limitations of an imaging radar in low-earth orbit.

Description. This experiment utilizes an imaging radar which employs a side-looking synthetic aperture technique. The experiment also uses the imaging radar to record radar return data on photographic film from which post-flight processing can provide accurate earth surface maps for use in analytical evaluations of basic radar technology.

The imaging radar and antenna mount configurations are shown in Figures C-25 and C-26, respectively. A block diagram of the imaging radar experiment is illustrated in Figure C-27.

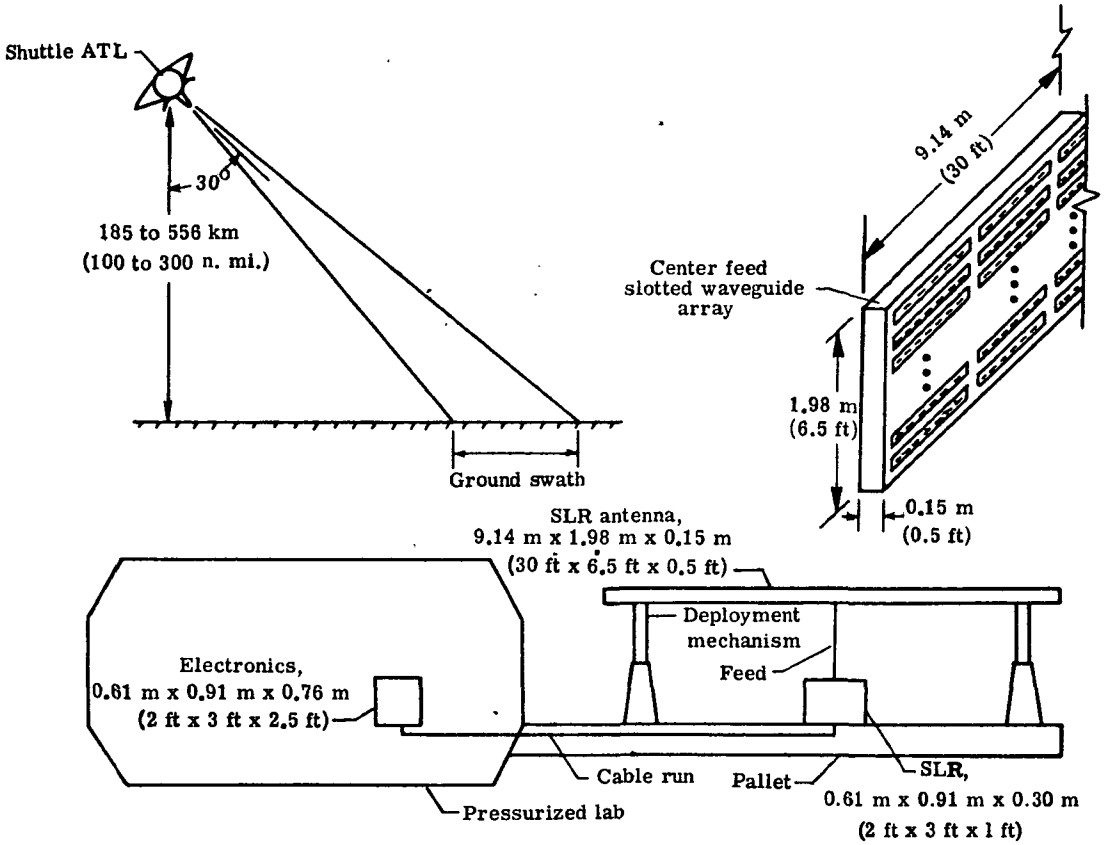


Figure C-25. Imaging Radar Configuration

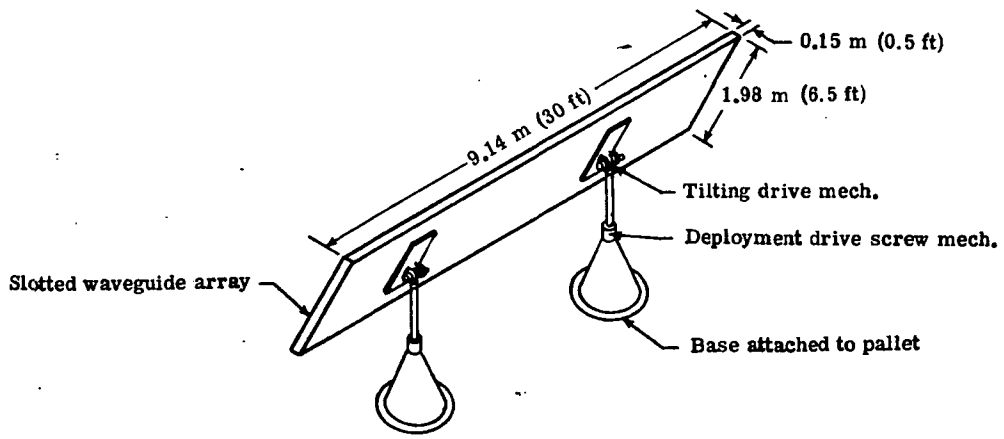


Figure C-26. Imaging Radar Antenna Mount

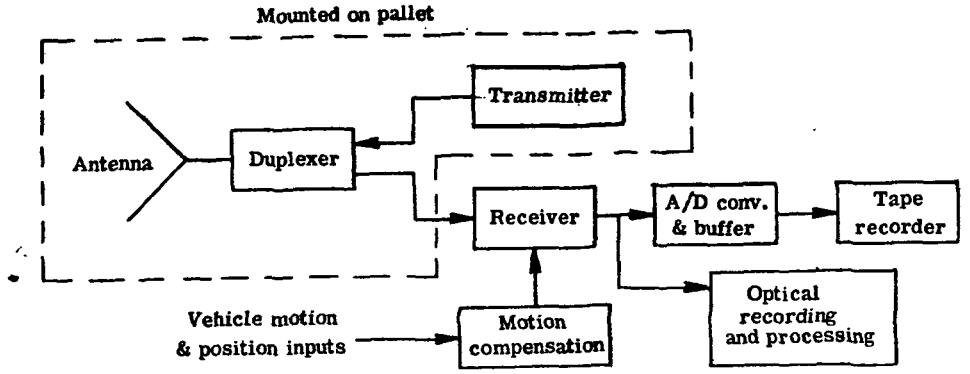


Figure C-27. Block Diagram of Imaging Radar Experiment

Physical Parameters. EO-8 (XST008)

Equipment		Qty	Location	Size (ft)			Vol. (ft^3)	Weight (lb)
Ref No.	Name			W/dia	H	L		
ST017	Spectrum analyzer	1	Internal	1.58	0.58	1.5	1.4	30
ST025	TV camera	1	External	0.25	0.5	0.67	0.08	5
ST154	Radar electronics*	1	External	2.0	3.0	2.5	15.0	600
ST155	Antenna*	1	External	6.5	0.5	30.0	97.5	1000
ST157	C/D console	1	Internal	2.0	3.0	2.5	15.0	60
ST273	Optical recorder	1	Internal	5.0	2.0	2.0	20.0	100
ST287	Electronics		Internal					

*Same as XST006, Search and Rescue Aids.

Configuration. Refer to Figures C-25 and C-26

Electrical/Data Requirements. EO-8 (XST008)

Equipment		Power (watts)		Data	
Ref. No.	Name	Standby	Operate	Form	Rate
ST017	Spectrum analyzer	50	50	A	-
ST025	TV camera	-	50	D	-
ST154	Radar electronics	-	900		
ST155	Antenna	-	-	-	-
ST157	C/D console	-	20	-	-
ST273	Optical recorder	25	250	D	-
ST287	Electronics				

Data runs are to be made in an earth-looking orientation at approximately a 60-degree depression angle. Geographical reference and meteorological data to be taken for correlation with basic radar images.

Pointing and Stability Requirements. Antenna requirements are as follows:

Area	Accuracy (deg)	Duration (sec)	Stability (deg)	Stability Rate (deg/sec)
Shuttle pointing requirement	0.5	1800	0.5	0.1
Final instrument-pointing capability	0.001	180	0.001	0.001

Field of View. Antenna pointing requires a depression angle of from 45 to 60 degrees for a side-looking view of the earth surface. A roll maneuver of the Shuttle to achieve pointing will simplify hardware design, but will impact simultaneous operation of other experiments. Further analysis to be performed.

Mission Operation. Experiment is to be operated from an altitude of 100 to 300 nmi and an inclination of 30 to 90 degrees. This experiment is to be performed simultaneously with XST006, Search and Rescue Aids Experiment.

EVA Activity. None

Crew Function. Set up and turn on equipment, monitor equipment operation, operate and secure data storage, and secure equipment for return flight.

Consumables

Film: 10 lb, 0.2 ft^3
Magnetic tape: 20 lb, 0.4 ft^3
Cryogenics: None

Environmental Requirements. EO-8 (XST008)

Operational Status	Temperature (°K)	Relative Humidity (%)	Cleanliness (Class)	Acoustics (dB)	Acceleration (g)
OPERATING					
Internal Equip.	295 ± 5	55 ± 25	300,000	60	0.001
External Equip.					
NON-OPERATING					
Internal Equip.	295 ± 20	50 ± 45	300,000	145	9.0
External Equip.	283 ± 83		300,000	145	9.0

Development Status. Basic radar techniques have been developed and aircraft flight experiments using side-looking radars have been successfully completed. Further design analysis is required to define hardware specifications and establish a development schedule.

EXPERIMENT EO-9 (XST009)

RF Noise

Objective. The purpose of this experiment is to measure the electromagnetic interference at orbital altitudes and in the frequency spectrom of 0.4 to 15 GHz.

Description. The determination of the amount and type of noise, the frequency of transmission, the effective radiated power, and the geographical location of noise-generating systems will allow the allocation and utilization of frequencies to be optimized.

This experiment employs a wide-range spectrum analyzer to measure the interference levels at orbital altitudes. The receiving system is capable of receiving a fixed frequency, electronically scanning the complete frequency spectrum of 0.4 to 15 GHz, or scanning any particular segment within the range of the receiver.

A computer program will be used to manipulate the data received from the spacecraft, tabulate the results, determine the power flux density upon a given orbit sphere, and locate the terrestrial emitters responsible for this power flux density.

Initial observations will be limited to the highly populated areas of North America, South America, and Europe. Follow-on flights at different orbit altitudes will be necessary to complete earth coverage and to determine the ability to extrapolate noise measurements from one orbit sphere to another.

Physical Parameters. EO-9 (XST009)

Equipment		Qty	Location	Size (ft)			Vol. (ft^3)	Weight (lb)
Ref No.	Name			W/dia	H	L		
ST008	Data Recorder	1	Internal	1.6	.9	1.6	2.3	100
ST025	TV Camera	1	Internal	.25	.5	.67	.08	5
ST026	TV Monitor	1	Internal	1	1	1.5	1.5	25
ST127	RF Receiver & Control Unit	1	Internal	1.6	.5	1.25	1	15
ST131	Antenna	4	External	10	-	4	314	35
ST137	Power Supply	1	Internal	1.6	1	1	1.6	100
ST276	Antenna Mount*	1	External	7	-	5	192	-

*Extends to 13 feet on .75 foot diameter column.

Configuration. Not available.

Electrical/Data Requirements. EO-9 (XST009)

Equipment		Power (watts)		Data	
Ref. No.	Name	Standby	Operate	Form	Rate
ST008	Data Recorder	25	250	D	-
ST025	TV Camera	0	50	-	-
ST026	TV Monitor	-	100	Display	-
ST127	Receiver/Control Unit	-	75	-	-
ST131	Antenna	-	-	-	-
ST137	Power Supply	-	20	-	-
ST276	Antenna Mount	-	-	-	-

Pointing and Stability Requirements. The antenna requirements relative to Shuttle pointing, mount pointing at the inner gimbal, and the final instrument pointing capability are as follows:

Accuracy (deg)	Duration (sec)	Stability (deg)	Stability Rate (deg/sec)
0.5	*	0.5	0.1

*Continuous scan up to 6 to 8 hours per day.

Field of View. The instantaneous and total field of view for both the antennas and the TV camera are 1.0 degree. The system requires the capability of being able to boresight and monitor antenna from interior of experiment module.

Mission Operation. Experiment to be conducted from a 100 to 300 nmi altitude at an orbit inclination of 60 to 90 degrees.

EVA Activity. None

Crew Functions. Monitor experiment on panoramic display, perform real-time analysis and make decisions for setting receiver parameters, and boresight the high-gain antenna on terrestrial emitters.

Consumables

Magnetic tape: 5 lb, 0.1 ft^3
Film: None
Cryogenics: None

Environmental Requirements. EO-9 (XST009)

Operational Status	Temperature (°K)	Relative Humidity (%)	Cleanliness (Class)	Acoustics (dB)	Acceleration (g)
Operating					
Internal Equip	295 ± 5	55 ± 25	300,000	60	.001
External Equip					
Non-Operating					
Internal Equip	295 ± 20	50 ± 45	300,000	145	9.0
External Equip	283 ± 83		300,000	145	9.0

Development Status. Development is proceeding on an experiment for measuring EMI at orbital altitudes and the necessary receiving system to measure this noise. A receiving system that may be applicable is being developed for NASA under an AAFE contract (NAS1-11465) by National Scientific Laboratories, Inc.

PHYSICS AND CHEMISTRY

Six experiments have been identified in the Physics and Chemistry area. Three involve *in situ* measurements of the environment near the spacecraft, two utilize the Shuttle as a platform for remote measurements, and one makes use of the zero-gravity environment of the spacecraft to perform laboratory-type experimentation.

EXPERIMENT PH-1 (XST014)

Spacecraft Wake Dynamics

Objective. The purpose of this experiment is to determine the parameters governing the flow around ionospheric satellites. Of particular interest is the spatial extent and properties of the wake region of the spacecraft.

Description. The wake of a large body is created primarily by the body sweeping out ions from the ambient plasma and thereby causing large disturbances in the local ion and electron densities. In the interpretations of the measurements of geophysical properties made with satellite-borne instrumentation, it is important to determine the effects of these satellite-caused perturbations.

A block diagram of the spacecraft wake dynamics experiment designed to investigate these effects is shown in Figure C-28. The parameters to be measured include the ion and electron density and temperature. Determination of the neutral gas composition and density will also be determined. These measurements are to be correlated with the vehicle potential, ambient magnetic field, and solar ultraviolet flux.

Sensors to be used for these measurements include a retarding potential analyzer for density and potential measurements, a mass spectrometer for ion analysis and neutral gas composition, a flux-gate magnetometer for magnitude and direction of magnetic fields, and electrostatic probes for fluctuating electric field measurements.

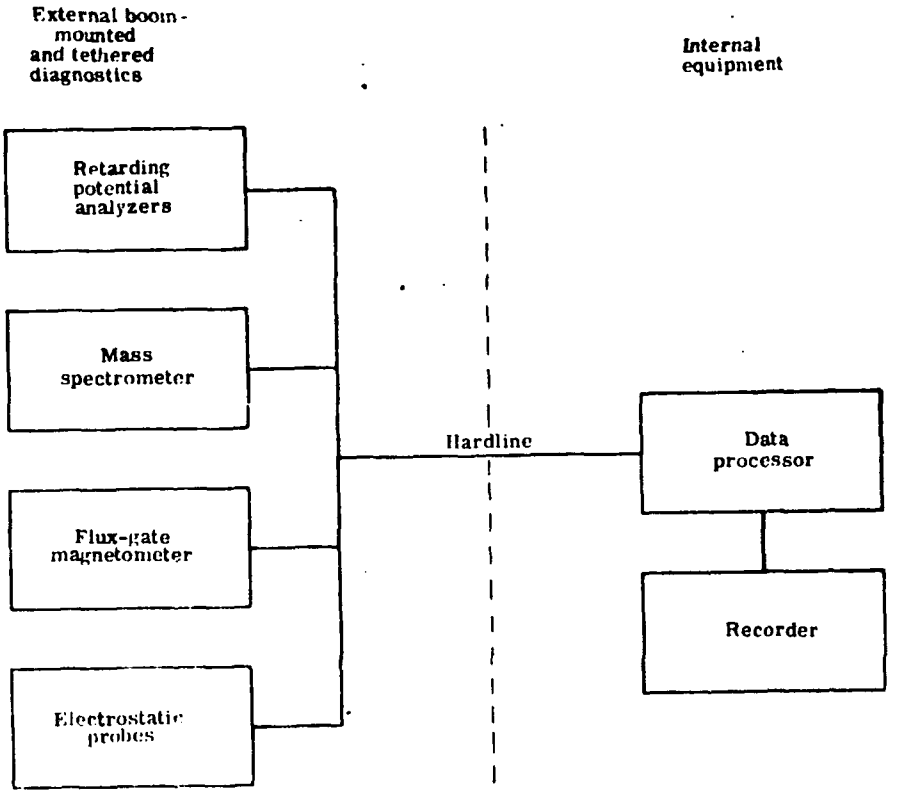


Figure C-28. Block Diagram of Spacecraft Wake Dynamics Experiment

Physical Parameters. PH-2 (XST014)

Equipment		Qty	Location	Size (ft)			Vol. (ft^3)	Weight (lb)
Ref No.	Name			W/dia	H	L		
ST008	Tape Recorder	1	Internal	1.6	.9	1.6	2.3	100
ST035	Data Processor	1	Internal	1	1	1	1	10
ST037	Potential Analy	4	External	.5	-	1	.196	4
ST038	Mass Spectro-meter	2	External	.5	-	1	.196	10
ST039	Magnetometer	2	External	1	-	1	.785	20
ST040	Electrostatic Probes	4	External	1.25	-	-	1.02	4
ST041	C/D Console	1	Internal	4	6	2	48	200
ST042	Boom	2	External	1	-	4.1*	3.2	22
ST043	Tether	1	External	-	-	750	.01	9

*Deploys to 75 feet

Configuration. Not available.

Electrical/Data Requirements. PH-1 (XST014)

Equipment		Power (watts)		Data	
Ref. No.	Name	Standby	Operate	Form	Rate
ST008	Tape Recorder	25	250	D	-
ST035	Data Processor	10	10	D	-
ST037	Potential Analyzer		90	A	1 MHz
ST038	Mass Spectrometer		110	D	10 KBPS
ST039	Magnetometer	3	5	D	900 BPS
ST040	Electrostatic Probes	1.6	1.6	D	150 BPS
ST041	C/D Console	200	200	Displays	-
ST042	Boom	-	-	-	-
ST043	Tether	-	-	-	-

Pointing and Stability. None

Field of View. None

Mission Operations. Data collection can be intermittent, but each collection period should extend over several hours and cover both day and night portions of the orbit.

EVA Activity. None

Crew Function. Control booms and tethered probes, perform experiment, and maintain equipment.

Consumables

Magnetic tape: 10 lb, 0.2 ft^3
Film: None
Cryogenics: None

Environmental Requirements. PH-1 (XST014)

Operational Status	Temperature (°K)	Relative Humidity (%)	Cleanliness (Class)	Acoustics (dB)	Acceleration (g)
Operating					
Internal Equip	295 ± 5	55 ± 25	300,000	60	.001
External Equip					
Non-Operating					
Internal Equip	295 ± 20	50 ± 45	300,000	145	9.0
External Equip	283 ± 83		300,000	145	9.0

Development Status. Instrument requirements are state of the art. Control of the tethered probes will require development.

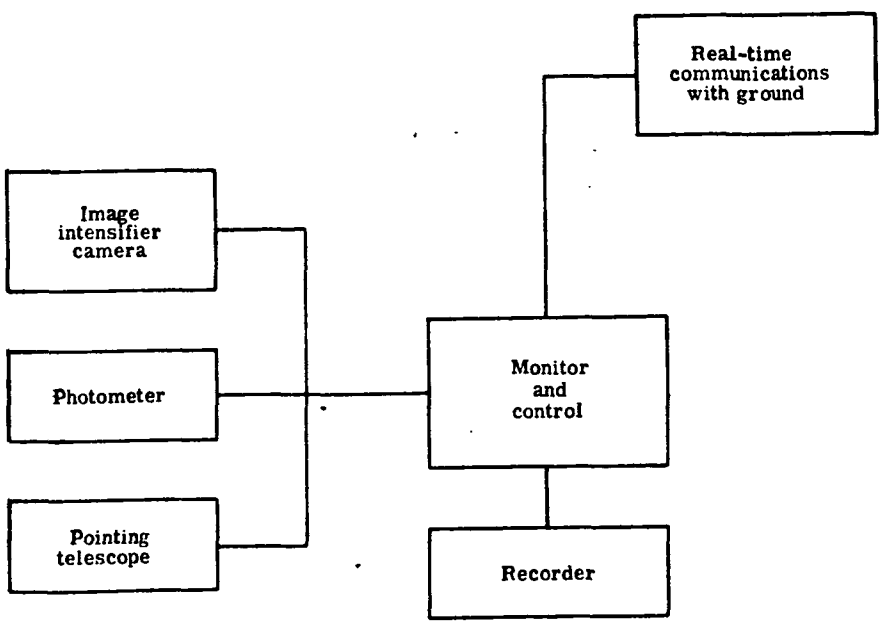
EXPERIMENT PH-2 (XST015)

Barium Cloud Release on Sunward Side of Earth

Objective. The purpose of this experiment is to monitor the natural magnetospheric plasma convection patterns on the sunward side of the earth.

Description. A knowledge of the natural magnetospheric plasma convection patterns on the sunward side of the earth is necessary for any detailed understanding of the interaction of the solar wind with the geomagnetic cavity, the mechanism of natural injection of particles into the magnetosphere, the interaction of the outer magnetosphere with the ionosphere, and the nature of magnetic storms and auroral processes. The barium ion cloud technique has been proven capable of measuring these electric fields in the magnetosphere. It is constrained, however, by the need for darkness at the observation sites along with clear weather simultaneously at several sites. With observations from the Shuttle, whose position with time is known very accurately, it is possible to triangulate the cloud motion through successive photographs from different locations.

A block diagram of the barium cloud release experiment is shown in Figure C-29. The experiment utilizes a relatively small rocket to boost a barium shaped charge to a height of a few hundred kilometers. The charge is then fired upward along a magnetic field line such that the barium cloud rises upward to a height of several earth radii in the magnetosphere. A photographic camera with an image intensifier and a photometer are used to observe the barium plasma cloud. Measurements consist of photographs and photometer readings. Close coordination with the rocket launch is required. The clouds will be released in such areas as in the vicinity of the magnetopause neutral points and points above and below the plasma-pause boundary.



C-29. Block Diagram of Barium Cloud Release Experiment

Physical Parameters. PH-2 (XST015)

Equipment		Qty	Location	Size (ft)			Vol. (ft^3)	Weight (lb)
Ref No.	Name			W/dia	H	L		
ST008	Tape Recorder	1	Internal	1.6	.9	1.6	2.3	100
ST025	T V Camera	1	External	.25	.5	.67	.08	5
ST150	Camera and Intensifier	2	External	.86	2	3.84	6.6	305
ST151	Photometer	1	External	1	2	1	2	50
ST152	Pointing Telescope	1	Internal	.2	--	1	.031	5
ST153	C/D Console	1	Internal	1.58	2.25	2	7.1	200
ST278	Framing Camera	1	External	.86	2	1.9	3.27	65
ST279	Lens Cover Motor	1	External					2
ST280	Mounting Plate	1	External	4	.08	4.33	1.39	124
ST281	Slide & Actuator	2	External					75
ST282	Window	1	External					160

Configuration. See Figures C-30 and C-31.

Electrical/Data Requirements. PH-2 (XST015)

Equipment		Power (watts)		Data	
Ref. No.	Name	Standby	Operate	Form	Rate
ST008	Tape Recorder	25	250	D	--
ST025	TV Camera	--	50	--	--
ST150	Camera & Intensifier	--	2500	--	--
ST151	Photometer	25	25	D	2.5 KBPS
ST152	Pointing Telescope	--	--	--	--
ST153	C/D Console	--	30	--	--
ST278	Framing Camera	--	--	--	--
ST279	Lens Cover Motor	--	200	--	--
ST280	Mounting Plate	--	--	--	--
ST281	Slide & Actuator	--	--	--	--
ST282	Window	--	--	--	--

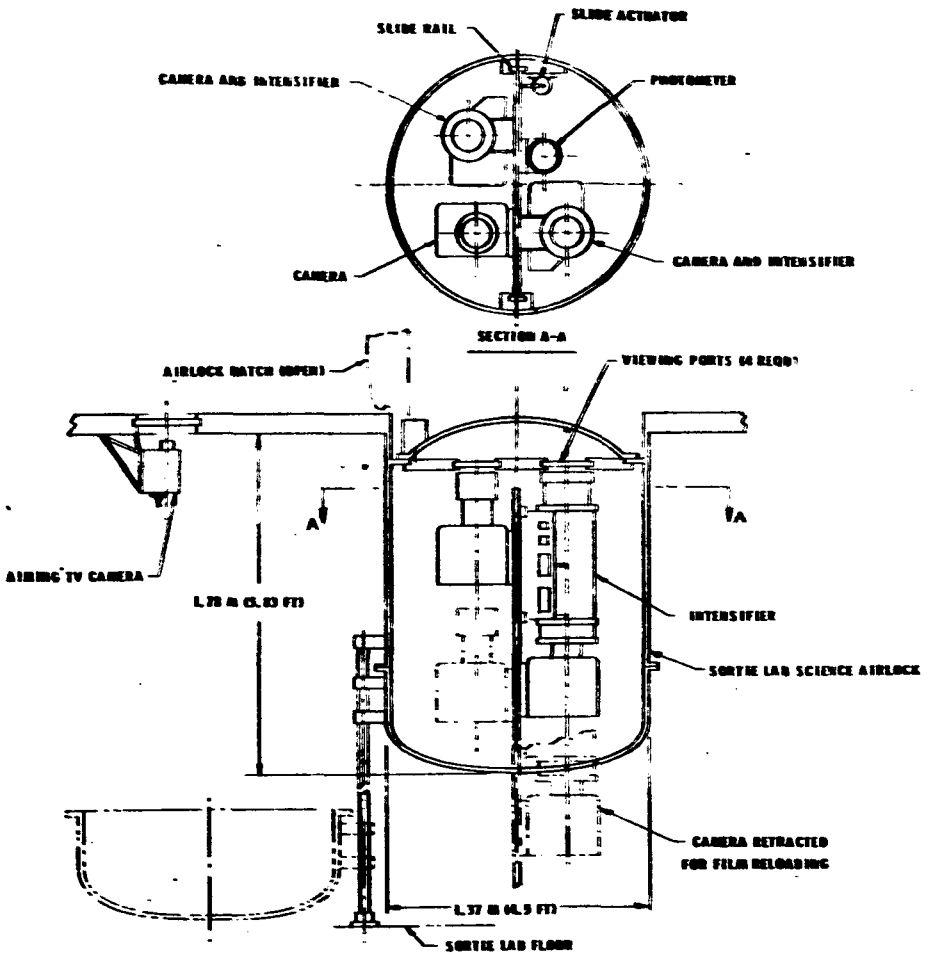


Figure C-30. Airlock Mount Configuration

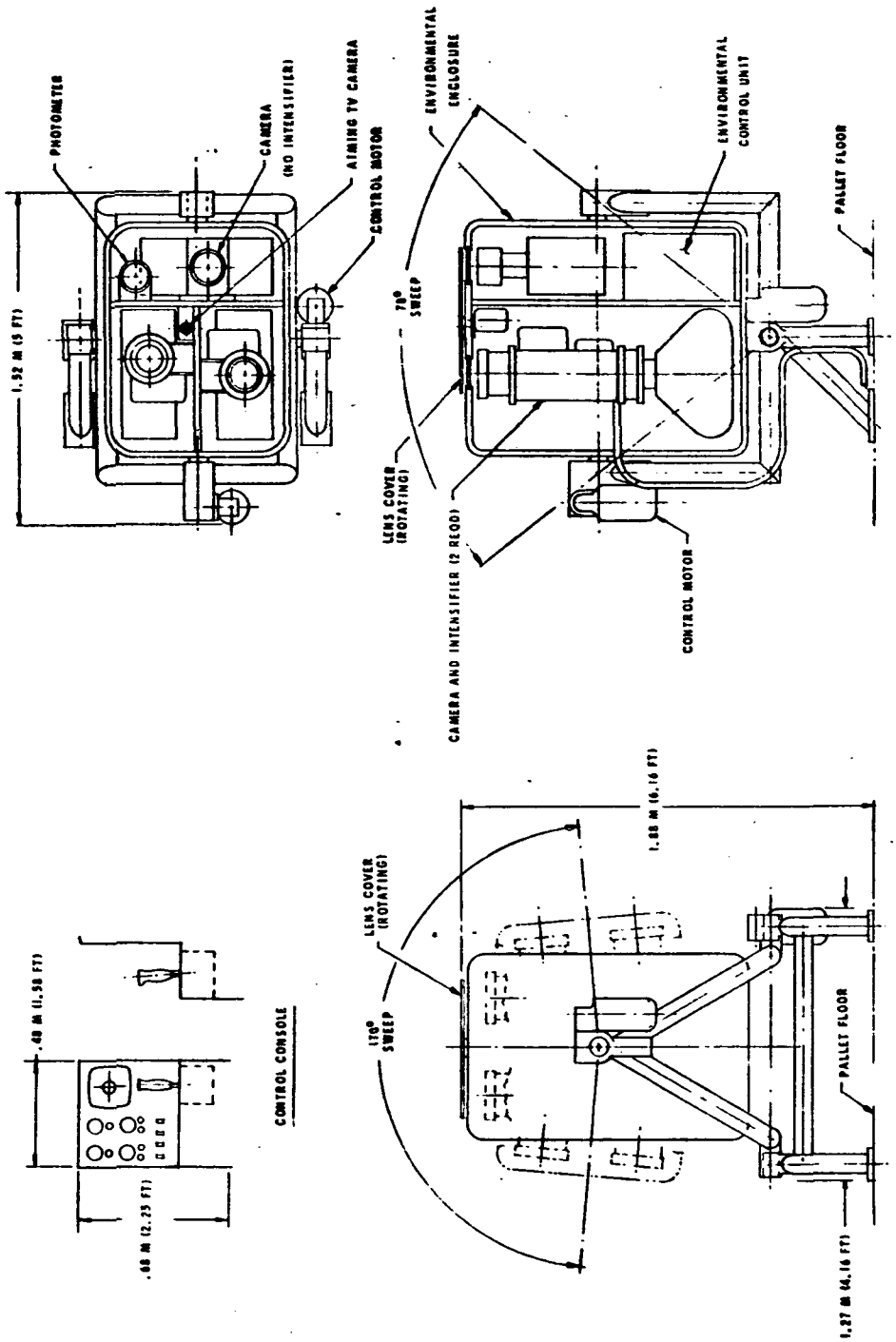


Figure C-31. Pallet Mount Configuration

Pointing and Stability. The requirements for both the pointing telescope (ST152) and the camera/image intensifier are as follows:

PARAMETER	ACCURACY (Deg)	DURATION (Sec)	STABILITY (Deg)	STABILITY RATE (Deg/Sec)
Shuttle Pointing Requirement	.5	2500	.5	.1
Mount Pointing Requirement*	.1	2400	.1	.02
Final Instru. Pointing Capability	.1	2400	.1	.02

*Accuracy required at inner gimbal.

Field of View. The experiment requires close coordination with the launch of the rocket from the ground. The barium cloud will have to be acquired and tracked from the spacecraft. This involves changing the attitude of the spacecraft to keep the cloud within view for a tracking angle of up to 170 degrees. The field-of-view requirements are as follows:

EQUIPMENT		FIELD OF VIEW	
Ref. No.	Name	Instantaneous	Total
ST150	Camera & Intensifier	5	170
ST152	Pointing Telescope	1	170

Mission Operation. The observations are required for as long as the orbit will permit so that the line of sight will rotate through 170 degrees. Under certain conditions, the cloud might remain visible for a long duration to permit reacquisition on a second pass. The barium cloud experiment is to be operated twice throughout the mission.

EVA Activity. None

Crew Functions. Set up equipment, initiate experiment, coordinate operation with ground and rocket launch facility, maintain equipment, locate barium cloud and maintain cloud within instrument field of view, monitor operation and data recording, and secure equipment at end of experiment operation.

Consumables

Film: 10 lb, 0.2 ft^3
Magnetic tape: TBD
Cryogenics: None

Environmental Requirements. *PH-2 (XST015)*

Operational Status	Temperature (°K)	Relative Humidity (%)	Cleanliness (Class)	Acoustics (dB)	Acceleration (g)
OPERATING					
Internal Equip.	295 ± 5	55 ± 25	300,000	60	.001
External Equip.					
NON-OPERATING					
Internal Equip.	295 ± 20	50 ± 45	300,000	145	9.0
External Equip.	283 ± 83		300,000	145	9.0

Development Status. Equipment procurement and data reduction planning activities would require approximately 2 years at 6 man-years/year.

EXPERIMENT PH-3 (XST016)

Optical Properties of Aerosols

Objective. The purpose of this experiment is to obtain a detailed knowledge of the interrelationship between the size, shape, concentration and composition of aersols and their optical properties under various meteorological conditions.

Description. The interaction of atmospheric particles with solar and terrestrial radiation plays an important role in the determination of the earth heat budget. Changes in the atmospherical particulate matter content may change the global albedo, which ultimately leads to a change in the mean temperature and climate.

This experiment consists of a zero-gravity environmental chamber to provide a means of making microscopic observations of individual particles in controlled meteorological conditions without movement from convection and without the need for a solid support for the individual particles.

The optical properties of typical particles suspended in the zero-gravity environmental chamber are to be measured and the particles observed microscopically as the pressure, temperature and dewpoint are changed. Observations will be recorded in the form of individual photographs along with high speed and time-lapse photography as seen through the microscope. A block diagram of the experiment apparatus is presented in Figure C-32. The experiment equipment is shown in Figure C-33.

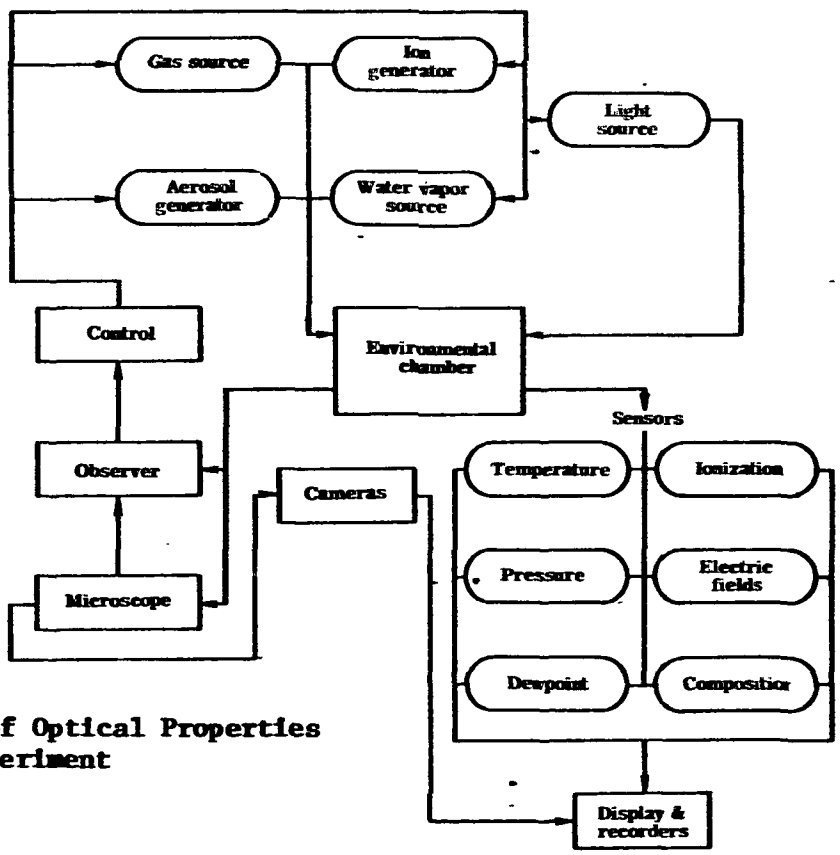
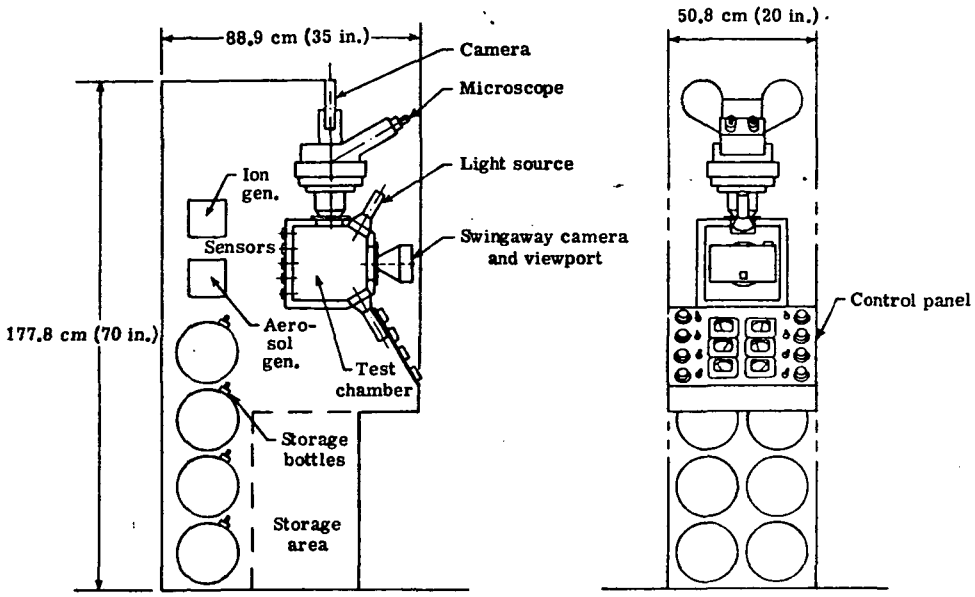


Figure C-32. Block Diagram of Optical Properties of Aerosols Experiment



C-33. Equipment Layout for Optical Properties of Aerosols Experiment

Physical Parameters. PH-3 (XST016)

Equipment		Qty	Location	Size (ft)			Vol. (ft^3)	Weight (lb)
Ref No.	Name			W/dia	H	L		
ST008	Tape Recorder	1	Internal	1.6	.9	1.6	2.3	100
ST019	Still Camera	1	Internal	.5	.5	.5	.125	5
ST045	Gas Source	8	Internal	1.5	--	3.34	5.9	30
ST046	Aerosol Generator	1	Internal	.5	.5	1	.25	5
ST047	Ion Generator	1	Internal	.5	.5	1	.25	10
ST048	Water Vapor Source	2	Internal	1	--	2	1.57	20
ST049	Light Source	1	Internal	.5	--	3	.59	20
ST050	Environ.Chamber	1	Internal	1	2	1.5	3	50
ST051	Microscope	1	Internal	.25	--	1	.049	10
ST052	Instrumentation Sensors		Internal					33
ST053	C/D Panel	1	Internal	1.7	3	2.9	15	60
ST054	Cine Camera	1	Internal	.5	1	1	.5	20

Configuration. See Figure C-33.

Electrical/Data Requirements. PH-3 (XST016)

Equipment		Power (watts)		Data	
Ref. No.	Name	Standby	Operate	Form	Rate
ST008	Tape Recorder	25	250	D	
ST019	Still Camera	0	5	Film	—
ST045	Gas Source	0	0	—	—
ST046	Aerosol Generator	0	20	—	—
ST047	Ion Generator	0	20	—	—
ST048	Water Vapor Source	0	0	—	—
ST049	Light Source	0	50	—	—
ST050	Environ.Chamber	10	50	—	—
ST051	Microscope	0	10	Visual	—
ST052	Instrumen.Sensors	5	45	D	9 KBPS
ST053	C/D Panel	—	20	Displays	—
ST054	Cine Camera	0	100	Film	1000Frames

Environmental Requirements. PH-3 (XST016)

Operational Status	Temperature (°K)	Relative Humidity (%)	Cleanliness (Class)	Acoustics (dB)	Acceleration (g)
OPERATING					
Internal Equipment	295 ± 5	55 ± 25	300,000	60	.001
External Equipment					
NON-OPERATING					
Internal Equipment	295 ± 20	50 ± 45	300,000	145	9.0
External Equipment	283 ± 83		300,000	145	9.0

EVA Activity. None

Crew Functions. This experiment requires a high degree of on-board experimenter participation. The experimenter will initiate experiments utilizing the environmental chamber, make appropriate observations, and modify subsequent experimental procedures accordingly.

Consumables

Various gases: 44 lb, 1.0 ft^3
Water vapor source: 22 lb, 5 ft^3
Film: 11 lb, 0.1 ft^3
Magnetic tape: TBD

Various gases must be stored with pressures regulated from 0 to 15 psig, and with temperatures regulated from 223 to 293 K.

Development Status. Experiment hardware definition activity will follow completion of Zero-Gravity Cloud Physics Chamber Feasibility study being conducted by MSFC.

EXPERIMENT PH-4 (XST017)

Mapping of Upper Atmospheric Neutral Gas Parameters

Objective. The purpose of this experiment is to measure, on a global scale, the neutral number density of each constituent of the upper atmosphere and the temperature of the upper atmosphere as a function of latitude, longitude, height, and time using molecular-beam techniques.

These data, combined with independently determined time and space correlated density data, will provide the information necessary to completely define the structure of the upper atmosphere, to provide a basis for determining the day-to-night changes; to enable determination of diurnal, seasonal, and solar variations in the atmosphere; and to construct a dynamic model of the atmosphere.

Description. This experiment consists of a set of molecular beam mass spectrometers mounted on a boom and deployed into the undisturbed free stream through which the spacecraft is traveling to measure the neutral number density and temperature. The mass spectrometer system consists of a free-stream ion source, a quadrupole mass filter, an ion-counting collector system and associated electronics. Except for the electronics, the entire system must be vacuum-sealed during launch to protect the vacuum integrity of the instrument. After obtaining orbit, the instrument is opened and deployed into the free stream to avoid measuring surface-scattered gas. Illustrations of the instrumentation are presented in Figures C-34 and C-35.

An accurate determination of the number density of each gas is then obtained as a function of time and space as determined before flight. The data are to be recorded on a tape recorder for permanent record and displayed real-time on an oscilloscope. The data will be reduced by the on-board computer to permit changes in the flight plan for the purpose of examining unexpected or interesting scientific effects.

The gas temperature measurement technique consists of forming a molecular beam from the undisturbed free stream, and measuring the angular distribution of the beam flux density. The angular distribution of the beam flux is uniquely related to the temperature of the gas from which the beam is formed and is thus a direct measurement of the free-stream gas temperature. The measurement equipment consists of the apparatus which forms the main molecular beam and subsequently divides it into a set of sub-beams; ion sources for each of the sub-beams; mass filters and ion detectors for each sub-beam; and pulse-shaping, discriminating, and counting circuits for each detector. This system also, except for the electronics, must be sealed and evacuated during launch. The beam-forming apparatus must also be deployed into the undisturbed free stream.

Flight plan orbit parameters will be selected to yield maximum global data. Provisions for temporary modifications of the flight plan, based upon flight data, will be incorporated into the experimental procedure.

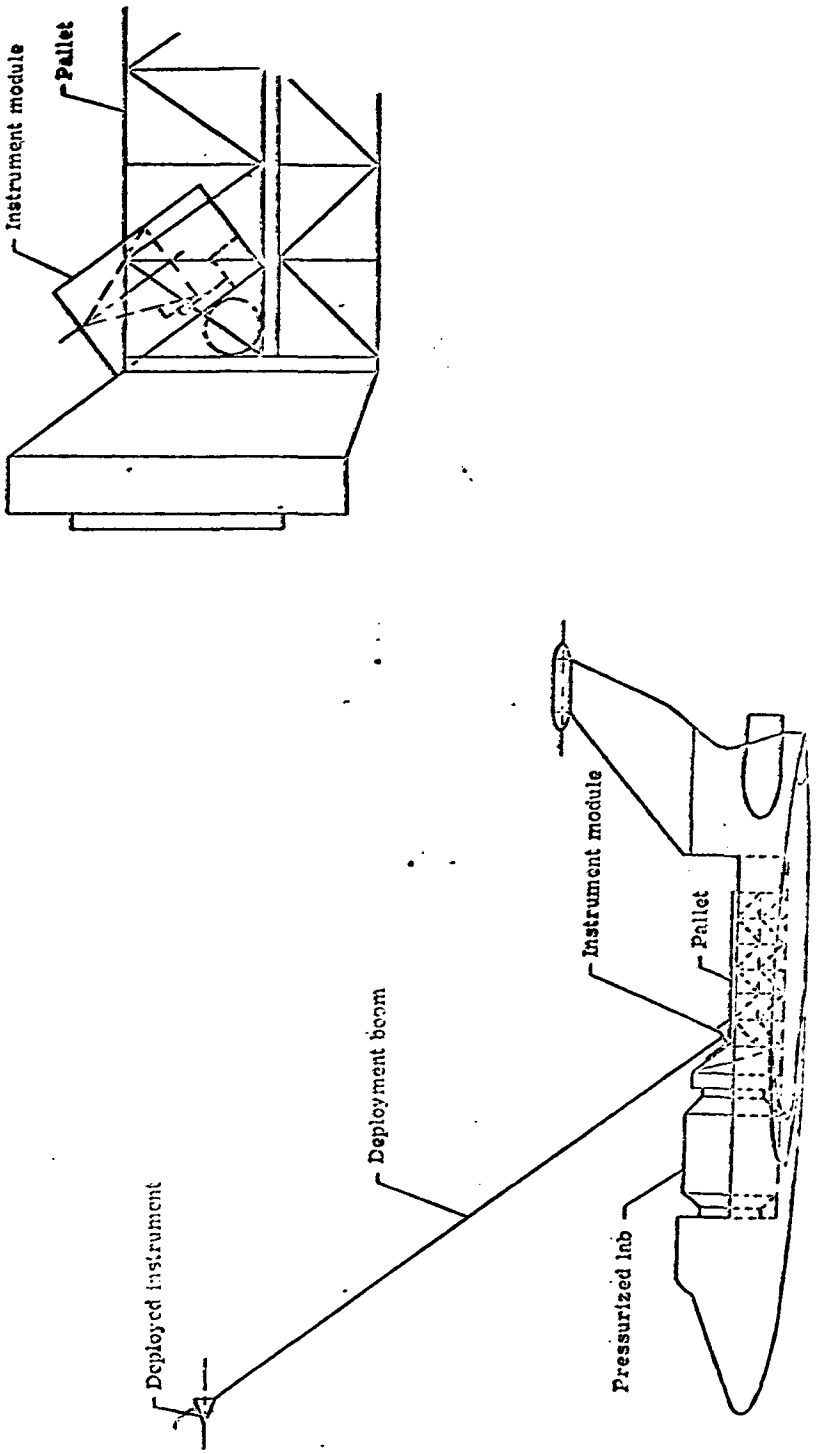
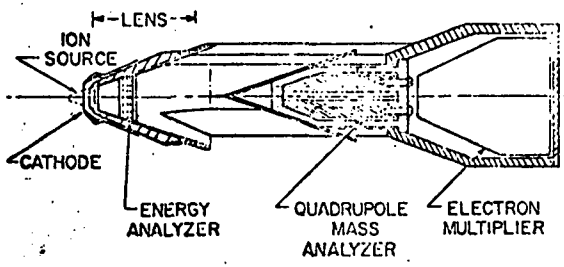
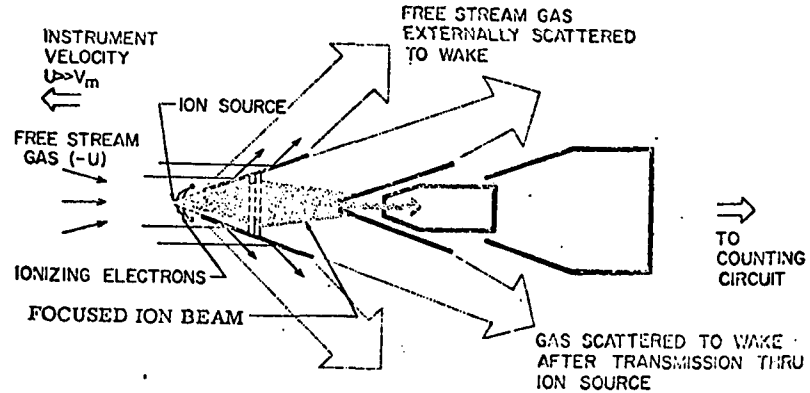


Figure C-34. Mass Spectrometer Diagnostic System



Cross-sectional view.



Functional schematic.

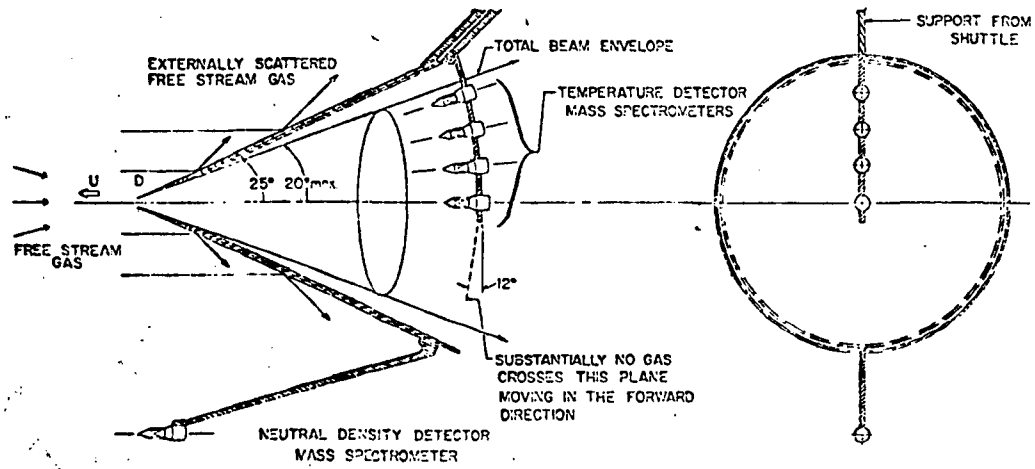


Figure C-35. Experiment Apparatus

Space Division
Rockwell International

Physical Parameters. *PH-4 (XST017)*

Equipment		Qty	Location	Size (Ft)			Vol	Wt
Ref No	Name			W/Dia	H	L	(Ft^3)	(lb)
ST007	Oscilloscope	1	Internal	1.6	.6	1.5	1.44	29
ST008	Data Recorder	1	Internal	1.6	.9	1.6	2.3	100
ST024	Computer	1	Internal	1.6	1	2	3.2	111
ST035	Data Processing Equip	1	Internal	1	1	1	1	10
ST042	Boom	1	External	1	-	1.25	1	50
ST055	Molecular Beam Mass Spec	5	External	.2	-	.8	.024	.5
ST056	Tape Recorder	1	Internal	1.5	1	2.5	3.75	130
ST057	C/D Console	1	Internal	1	1	2	2	50
ST058	Ion Source	1	External	.1	.1	.1	.001	.1
ST059	Ion Counting Collector Sys*	1	External	.5	.5	.5	.125	10
ST060	Molecular Beam Subdivider	1	External	3	-	4	28	177
ST061	Mass Filter/Ion Detector*	1	External	-	-	-	-	-
ST062	Electronics Support	1	External	1	.5	.5	.25	10
ST267	Instrument Canister	1	External	3.3	-	6	50.5	88

*Part of ST055

Configuration. See Figures C-34 and C-35

Electrical/Data Requirements. PH-4 (XST017)

Equipment		Power (W)		Data	
Ref No	Name	Stby	Operate	Form	Rate
ST007	Oscilloscope	30	92	CRT	-
ST008	Data Recorder	25	250	D	-
ST024	Computer	100	800	D	-
ST035	Data Processing Equip	10	10	D	-
ST042	Boom	0	135	-	-
ST055	Molecular Beam Mass Spec	10	100	D	500 BPS
ST056	Tape Recorder	90	600	A	-
ST057	C/D Console	-	120	-	-
ST058	Ion Source	10	20	D	100 BPS
ST059	Ion Counting Collector Sys	-	10	D	500 BPS
ST060	Molecular Beam Subdivider	-	-	-	-
ST061	Mass Filter/Ion Dectector	-	-	-	-
ST062	Electronics Support	-	10	-	-
ST267	Instrument Canister	-	-	-	-

Pointing and Stability. $\pm 2.0°$ pointing; 0.5 degree/sec stab. rate

Field of View. None

Mission Operation. A series of circular orbits with the orbit radius adjusted over the entire range is preferred. An elliptical orbit with perigee near insertion altitude and apogee as high as practical would be acceptable. A combination of orbits would also be acceptable. A large amount of meaningful data could be obtained even if the elliptical orbit could only be acquired for two or three passes. Any low earth orbit provides meaningful data.

EVA Activity. None

Crew Functions. Set up experiment, deploy and control booms, monitor experiment data, and implement changes in the vehicle space coordinates to investigate atmospheric variations of interest on a near-real-time basis. Experiment should be monitored every other revolution during instrument operation.

Consumables

Magnetic tape: 20 lb, 0.4 ft^3
Film: None
Cryogenics: None

Environmental Requirements. PH-4 (XST017)

Operational Status	Temp (°K)	Rel Hum (%)	Cleanliness (Class)	Acoustics (dB)	Accel. (g)
OPERATING					
Internal equipment	295 ± 5	55 ± 25	300,000	60	0.001
External equipment					
NON-OPERATING					
Internal equipment	295 ± 20	50 ± 45	300,000	145	9.0
External equipment	283 ± 83		300,000	145	9.0

Development Status. Estimated to be approximately 4 years through design and fabrication of flight hardware.

EXPERIMENT PH-5 (XST018)

Spacecraft Radiation Environment

Objective. The purpose of this experiment is to characterize the internal radiation environment of the Spacelab in terms of radiation type, energy, intensity, and direction. This information will provide an accurate description of the radiation dose received by the crew.

Description. For long-duration earth-orbit missions, the crew is continuously exposed to the secondary radiation from the relatively low intensities of cosmic rays, trapped electrons, and trapped protons impinging on the spacecraft. The intensities of electrons and protons increase rapidly on passage through the South Atlantic anomaly.

At present, relatively little is known of the effects on humans of protracted exposure to radiation. Without an accurate description of the internal radiation environment, there is no way to assess the actual biological damage to the crew members for long-term low-level radiation exposures.

The experiment will make detailed continuous measurement of the radiation types, energy, intensity, and direction. Information from this experiment will provide a more accurate radiation exposure record for each astronaut and thereby improve the quality of post-flight medical examinations. It will also permit assignment of an accurate radiation dose for each critical organ of the body such as bone marrow, eye lens, and stomach. Furthermore, this experiment will provide data on the effective shielding afforded by the spacecraft. A block diagram of the experiment is shown in Figure C-36.

This experiment will measure the energy, particle type, and intensity of charged particles penetrating the vehicle pre-sure shell. The energy range to be covered for protons is from 5 to 230 MeV, deutrons from 10 to 300 MeV, tritons from 15 to 230 MeV, helium -3 from 20 to 400 MeV, and alpha particles from 25 to 450 MeV. Electromagnetic radiation will be measured from 100 keV to 6 MeV. Neutron radiation will be measured from 0.5 to 15 MeV.

The charged-particle detector will use approximately 30 multiwire proportional counter planes separated by layers of varying thickness of tissue-equivalent plastic. This detector will measure rate of energy loss, direction, and range of charged particle. Analog signals from the detector are processed in real time by the on-board computer to give particle type, energy and biological radiation dose. A second identical charged-particle detector will be installed on the pallet to measure the charged-particle energy and flux. Data will be stored for post-flight analysis.

Electromagnetic radiation is to be measured with a cryogenically cooled lithium-drifted germanium detector which uses a charged-particle anticoincidence shield. Analog signals from this detector will also be processed in real time to determine the biological radiation dose from the electromagnetic radiation. Raw data will also be stored for post-flight analysis.

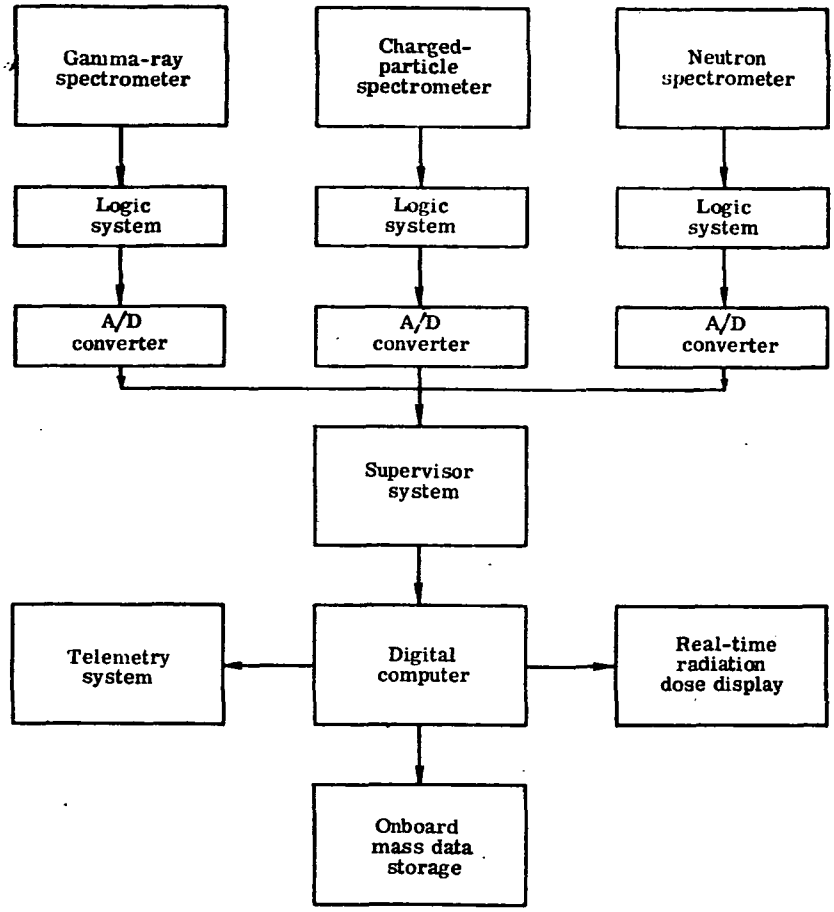


Figure C-36. Block Diagram of Spacecraft Radiation Environment Experiment

Neutron measurements will be performed with a liquid scintillator surrounded by a charged-particle anticoincidence shield. Pulse-shape discrimination is used to separate neutron events from those caused by electromagnetic radiation. Data analysis will be performed post-flight.

Several passive detectors such as film badges, thermoluminescent dosimeters and ion chambers will be used to compare with the results from the active sensors.

Physical Parameters. PH-5 (XST018)

Equipment		Qty	Location	Size (Ft)			Vol	Wt
Ref No	Name			W/Dia	H	L	(Ft^3)	(lb)
ST008	Tape Recorder	1	Internal	1.6	.9	1.6	2.3	100
ST024	Digital Computer	1	Internal	1.6	1	2	3.2	111
ST063	Gamma Ray Spec	1	Internal	.9	.9	1.6	1.3	22
ST064	Charged Particle Spec	2	*	1	2	2	4	80
STo65	Neutron Spectrometer	1	Internal	.5	.5	3	.75	20
ST066	Logic System	1	Internal	.3	.3	.15	.014	1
ST067	A/D Converter	1	Internal	1.6	.25	1	4	20
ST068	Supervisor System	1	Internal	.5	.5	1	.25	5
ST069	C/D Console	1	Internal	1.3	2	1.3	3.38	50
ST070	Film Badge	12	Internal	.16	.15	.016	.0004	.11
ST071	Thermoluminescent Dosimeter	4	Internal	.5	.4	.2	.04	1
ST072	Ion Chamber	4	External	.5	.5	3	.75	30
ST271	Cryogenic Coolant	1						

*One internal and one external

Configuration. **Not available.**

Electrical/Data Requirements. PH-5 (XST018)

Equipment		Power (W)		Data	
Ref No	Name	Stby	Operate	Form	Rate
ST008	Tape Recorder	25	250	D	-
ST024	Digital Computer	100	800	D	-
ST063	Gamma Ray Spec	10	10	D	1 KBPS
ST064	Charged Particle Spec	10	50	D	1 KBPS
ST065	Neutron Spectrometer	10	50	D	1 KBPS
ST066	Logic System	-	10	-	-
ST067	A/D Converter	25	25	-	-
ST068	Supervisor System	-	5	-	-
ST069	C/D Console	0	120	Display-	
ST070	Film Badge	0	0	-	-
ST071	Dosimeter	5	5	D	10 BPS
ST072	Ion Chamber	0	30	D	100 BPS
ST271	Cryogenic Coolant				

Pointing and Stability Requirements. None

Field of View. None

Mission Operation. Experiment to be conducted once per day, 5 times per mission.

Crew Functions. This experiment is designed to operate independently of the spacecraft crew. The experiment operates continuously. A periodic check by the crew is required to determine the pressure and flow rates in the charged-particle detector and to monitor the nitrogen supply for the electromagnetic detector. The crew is also required to maintain equipment, obtain data and secure equipment for return flight.

Consumables

Magnetic tape: 10 lb, 0.2 ft^3
Gas for detector: 10 lb, 0.2 ft^3
Liquid nitrogen: 30 lb, 0.4 ft^3
Film: None

The gas is required for the charged-particle detector and the liquid nitrogen for the germanium detector.

Environmental Requirements. PH-5 (XST018)

Operational Status	Temp (°K)	Rel Hum (%)	Cleanliness (Class)	Acoustics (dB)	Accel (g)
OPERATING					
Internal equipment	295 ± 5	55 ± 25	300,000	60	0.001
External equipment					
NON-OPERATING					
Internal equipment	295 ± 20	50 ± 45	300,000	145	9.0
External equipment	283 ± 83		300,000	145	9.0

Development Status. Development will require approximately 2 man-years per year for 6 years.

EXPERIMENT PH-6 (XST019)

Ultraviolet Meteor Spectroscopy from Near-Earth Orbit

Objective. The purpose of this experiment is to obtain high-quality meteor spectrographs in the wavelength region below the 3100-anstrom cutoff of the atmospheric zone.

Description. The study of meteoroids is important because of their potential hazard to spacecraft and the information they can provide on the evolution of the solar system. Current ground-based quantitative spectroscopy of meteor radiation provides data for determining elemental abundances in meteoroids in the wavelength region between 3100 and 9000 angstroms. Observations of meteors from above the atmospheric ozone region would extend the wavelength region below the 3100 angstrom ozone cutoff to approximately 1000 anstroms. A number of elements such as hydrogen, carbon, silicon, iron, and magnesium (which are suspected to be present in meteoroids) radiate strongly within this wavelength region.

In this experiment, three or more slitless spectrographs will be used to obtain spectra of meteors in the brightness range of +2 to -3 absolute meteor magnitude. The spectrograph complex consists of a Carruthers far-ultraviolet spectrograph for the spectral region of 500 to 1600 angstroms, an electronographic spectrograph for the spectral region of 1300 to 2100 angstroms, and a middle-ultraviolet panchromatic spectrograph for the spectral region of 2000 to 7000 angstroms. All of these spectrographs are near f/1 optical systems of the order of 100-mm focal length and 20 degrees field of view.

A photomultiplier detector will sense meteors in the field of view of the spectrographs and actuate the shutter mechanism and film advance. The spectrographs will operate when looking at the dark side of the earth. Exposure times will be on the order of one-second duration. A block diagram of the experiment is shown in Figure C-37. A sketch of the instruments is shown in Figure C-38.

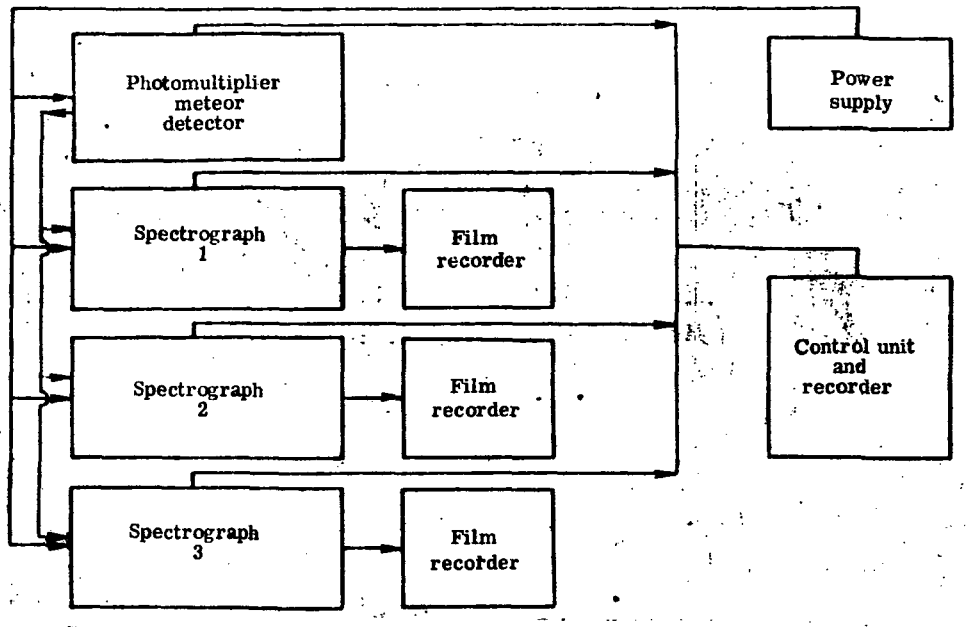


Figure C-37. Block Diagram of Ultraviolet Meteor Spectroscopy Experiment

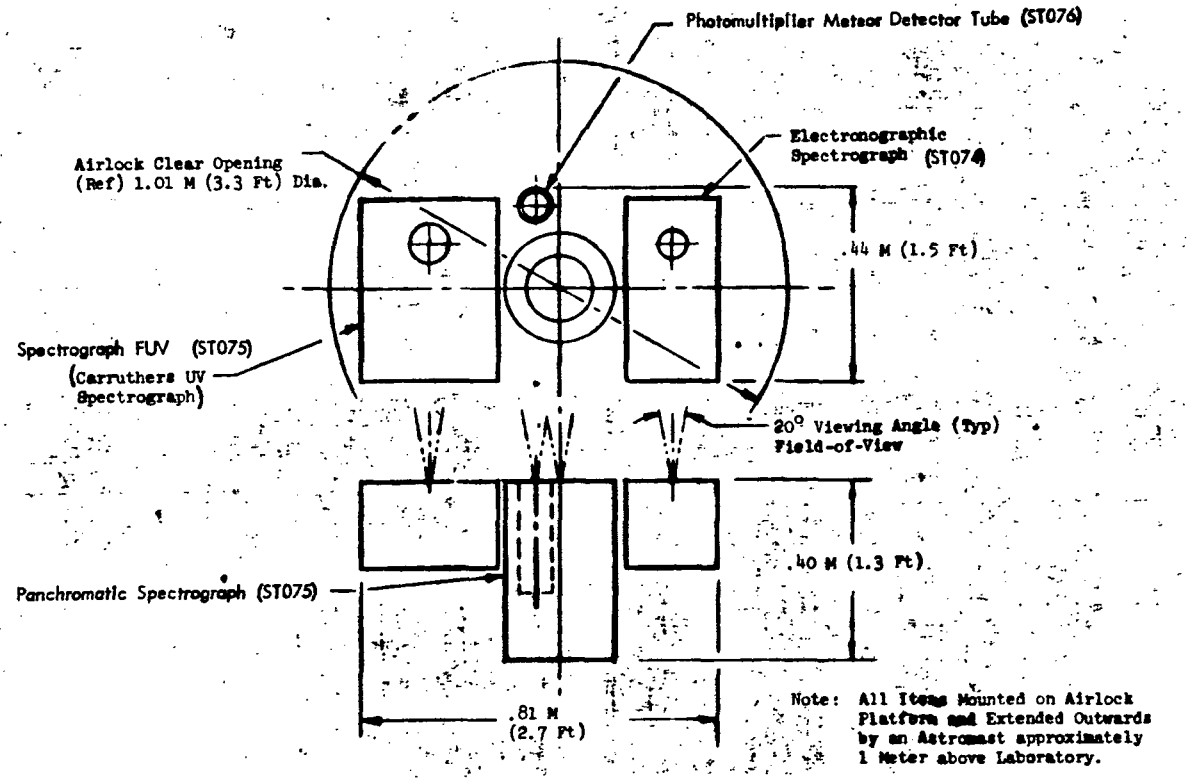


Figure C-38. Ultraviolet Meteor Spectroscopy Instruments

Physical Parameters. PH-6 (XST019)

Equipment		Qty	Location	Size (ft)			Vol. (ft^3)	Weight (lb)
Ref No.	Name			W/dia	H	L		
ST008	Tape recorder	1	Internal	1.6	0.9	1.6	2.3	100
ST073	FUV spectrograph	1	Airlock	1.0	0.66	1.25	0.83	35
ST074	Electronograph spectrograph	1	Airlock	0.66	0.66	1.25	0.545	35
ST075	Panchromatic spectrograph	1	Airlock	0.83	-	1.25	0.67	35
ST076	Photomultiplier detector	1	Airlock	0.25	-	0.83	0.035	15
ST077	C/D console	1	Internal	1.66	0.66	2.0	2.19	30
ST078	Airlock*	1	Internal					

* Experiment could be external if airlock not available.

Configuration. See Figure C-38.

Electrical/Data Requirements. PH-6 (XST019)

Equipment		Power (watts)		Data	
Ref. No.	Name	Standby	Operate	Form	Rate
ST008	Tape recorder	25	250	D	
ST073	FUV spectrometer	-	7	Film	1/sec
ST074	Elect. spectrograph	-	7	Film	1/sec
ST075	Panchro spectrograph	-	7	Film	1/sec
ST076	Photomultipler detector	2	2	D	100 bps
ST077	C/D console	-	15	-	-
ST078	Airlock	-	-	-	-

Pointing and Stability Requirements. The Shuttle pointing requirements and final instrument-pointing capability for the photomultiplier meteoroid detector are as follows:

Accuracy (deg)	Duration (sec)	Stability (deg)	Stability Rate (deg/sec)
1	1200	1	0.1

Field of View

Ref. No.	Name	Instantaneous FOV (deg)	Total FOV (deg)
ST073	FUV spectrometer	20	20
ST074	Elect. spectrograph	20	20
ST075	Panchro. spectrograph	20	20
ST076	Photomultiplier detector	20	20

Mission Operation. Observations are to occur on the dark side of the earth. The shutter is actuated when the meteor detector senses a meteor in the field of view or on command from the control unit. The observations run for the duration of the mission. The experiment is to be performed once per day, 7 times per mission.

EVA Activity. None

Crew Functions. This experiment is highly automated. The crew function is to utilize internal control panel to initiate experiment and to monitor instrument performance. The crew is also required to monitor data recording, terminate experiment, and secure instruments and data for return flight.

Consumables

Magnetic tape: 10 lb, 0.2 ft^3
Film: 10 lb, 0.2 ft^3
Cryogenics: None

Environmental Requirements. PH-6 (XST019)

Operational Status	Temperature (°K)	Relative Humidity (%)	Cleanliness (Class)	Acoustics (dB)	Acceleration (g)
OPERATING					
Internal Equip.	295 ± 5	55 ± 25	300,000	60	0.001
External Equip.					
NON-OPERATING					
Internal Equip.	295 ± 20	50 ± 45	300,000	145	9.0
External Equip.	283 ± 83		300,000	145	9.0

Development Status. Design, procurement, tests, and calibration of the middle-ultraviolet slitless spectrograph and meteor detection system are expected to require 3 years at 2 man-years per year.

The Carruthers spectrograph has been successfully used on Apollo 16. The electronographic camera has been successfully flown on a Aerobee rocket. Near-ultraviolet spectrographs and photomultiplier meteor detectors are routinely used by the NASA-LaRC Faint Meteor Spectra Patrol.

MICROBIOLOGY

Five experiments have been identified in the Microbiology discipline. These experiments involve both micro-organisms and mammalian cells and are proposed for accomplishment in space, either to utilize or investigate the effects of the weightless state.

EXPERIMENT MB-1 (XST020)

Colony Growth in Zero Gravity

Objective. The purpose of this experiment is to investigate the growth pattern of bacterial colonies in near-zero gravity.

Description. A clinostat has been used in the laboratory to demonstrate the effect of uniform gravity on bacterial colony growth. Observations of colony growth in a zero-gravity environment are needed for comparison, however, to establish the validity of the clinostat technique for simulating zero gravity.

A number of bacteria colonies to be observed are housed in the segmented center of a container which also serves as an incubator. The container has an internal light source, a cover, and a camera attachment on the front. Until ready for use, the container is stored in a refrigerator at 278 K.

To start the experiment the container is removed from the refrigerator, mounted in the laboratory, the incubator activated, a camera attached, and the light source turned on. Test observations are made by the camera which is sequenced automatically at 2-hour intervals for a 3-minute run. A total of 12 observations is required. All data are recorded on film and analyzed post-flight. At the end of the test program the camera is removed, the cover replaced and the container returned to cold storage.

The experiment equipment consists of a culture tube rack and light source, incubator container (310 $\pm$ 1 K), camera and refrigerator (278 K). The design, development and checkout of this experiment are simple and straightforward. No state-of-the-art developments are required and ground test baseline data are available.

The bacteria colonies are susceptible to changes in the acceleration level during incubation. Preliminary data reflect that acceleration levels should not exceed 10^{-3} g.

Physical Parameters. MB-1 (XST020)

Equipment		Qty	Location	Size (ft)			Vol. (ft^3)	Weight (lb)
Ref No.	Name			W/dia	H	L		
ST019	Still camera	1	Internal	0.25	0.5	0.5	0.063	5
ST049	Light source	1	Internal	*	*	*	*	*
ST079	Tube holder	1	Internal	0.43	0.26	0.13	0.014	5
ST080	Refrigerator	1	Internal	3.0	2.0	1.0	6.0	30
ST081	Experiment container	1	Internal	0.58	0.42	0.42	0.10	5

*Inside incubator (XST079)

Configuration. See Figure C-39.

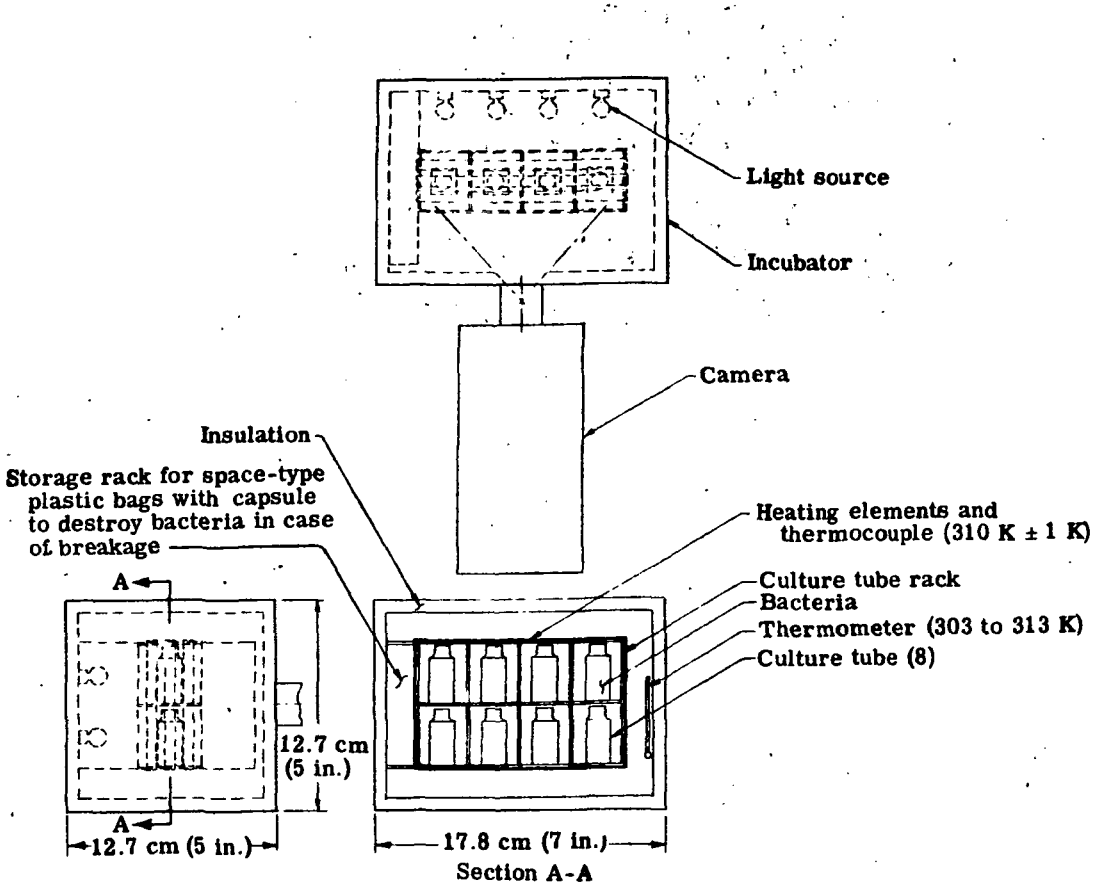


Figure C-39. Colony Growth in Zero-G Experimental Apparatus

Electrical/Data Requirements. MB-1 (XST020)

Equipment		Power (watts)		Data	
Ref. No.	Name	Standby	Operate	Form	Rate
ST019	Still camera	0	5	Film	-
ST049	Light source	0	100	-	-
ST079	Tube holder	0	30	-	-
ST080	Refrigerator	-	60	-	-
ST081	Experiment container	0	0	-	-

Pointing and Stability. Not applicable

Field of View. Not applicable

Mission Operation. A total of 12 observations are required. These are to be made at 2-hour intervals and the camera run time for each observation is 3 minutes. Changes in acceleration are not to occur during the incubation period. Estimates indicate that acceleration levels should not exceed 10^{-3} g.

EVA Activity. None

Crew Function. Remove container and light source from cold storage; mount in the laboratory; remove cover and attach camera; activate incubator, light source and automatic camera sequences; monitor operations; and deactivate and prepare for return flight. Crew is also required to destroy cell colonies in the event of breakage.

Consumables

Film: 5 lb, 0.1 ft^3
Magnetic tape: None
Cryogenics: None

Environmental Requirements. MB-2 (XST020)

Operational Status	Temperature (°K)	Relative Humidity (%)	Cleanliness (Class)	Acoustics (dB)	Acceleration (g)
OPERATING					
Internal Equip.	295 ± 5	55 ± 25	300,000	60	0.001
External Equip.					
NON-OPERATING					
Internal Equip.	295 ± 20	50 ± 45	300,000	145	9.0
External Equip.	283 ± 83		300,000	145	9.0

Development Status. The design, development and checkout of this experiment are simple and straightforward. No large preflight development effort is anticipated. No state-of-the-art developments are required and ground test baseline data are available.

EXPERIMENT MB-2 (XST021)

Interpersonal Transfer of Micro-Organisms in Zero Gravity

Objective. The purpose of this experiment is to investigate the interpersonal transfer of micro-organisms between crewmen in weightlessness.

Description. An important factor in the design of environmental control and life science support systems is a knowledge of the manner in which miro-organisms are transferred between crewmen in a closed environment. Although the absence of gravity is expected to affect the transfer pattern, this is difficult to simulate on the ground or assess analytically.

The experiment relies upon post-flight analysis of microbial samples collected by the crewmen throughout the mission. Prior to liftoff, a known trace organism and a crewman carrier are identified. The crewmen will periodically (at least once every 24 hours) collect microbial samples from their nose, throat and skin; label them; and place them in the incubator. This task will require about 15 minutes each sample-collection time.

After suitable incubation (24 to 48 hours) at 310 K, the samples are transferred to a 278-K refrigerator for preservation. Post-flight analysis will determine the transfer history of the trace organism. No special crew routines ore movements are required; however, a log of crewmen working in close proximity, and contacting one another when these working periods exceed a few minutes, is to be maintained.

The experiment will continue for the entire duration of the mission and includes preflight and post-flight examinations.

This experiment is closely related to the Sampling of Airborne Particles and Micro-Organisms experiment, and the post-flight data analyses will include the air-sampler data from that experiment.

Physical Parameters. MB-2 (XST021)

Equipment		Qty	Location	Size (ft)			Vol. (ft^3)	Weight (lb)
Ref No.	Name			W/dia	H	L		
ST080	Refrigerator	1	Internal	3.0	2.0	1.0	6.0	30
ST082	Collecting/storage device	1	Internal	1.3	1.08	0.5	0.7	10
ST083	Incubator	1	Internal	1.69	0.5	2.16	1.82	30

Congiguration. See Figure C-40.

Electrical/Data Requirements. MB-2 (XST021)

Equipment		Power (watts)		Data	
Ref. No.	Name	Standby	Operate	Form	Rate
ST080	Refrigerator	0	60	-	-
ST082	Collecting/storage device	-	-	-	-
ST083	Incubator	0	50	-	-

Pointing and Stability. Not applicable

Field of View. Not applicable

Mission Operation. The experiment is to continue for the duration of the mission and includes both preflight and post-flight examinations. There are to be 2 sample collection periods per day and a total of 7 per mission. Each crewman takes samples daily and processes them.

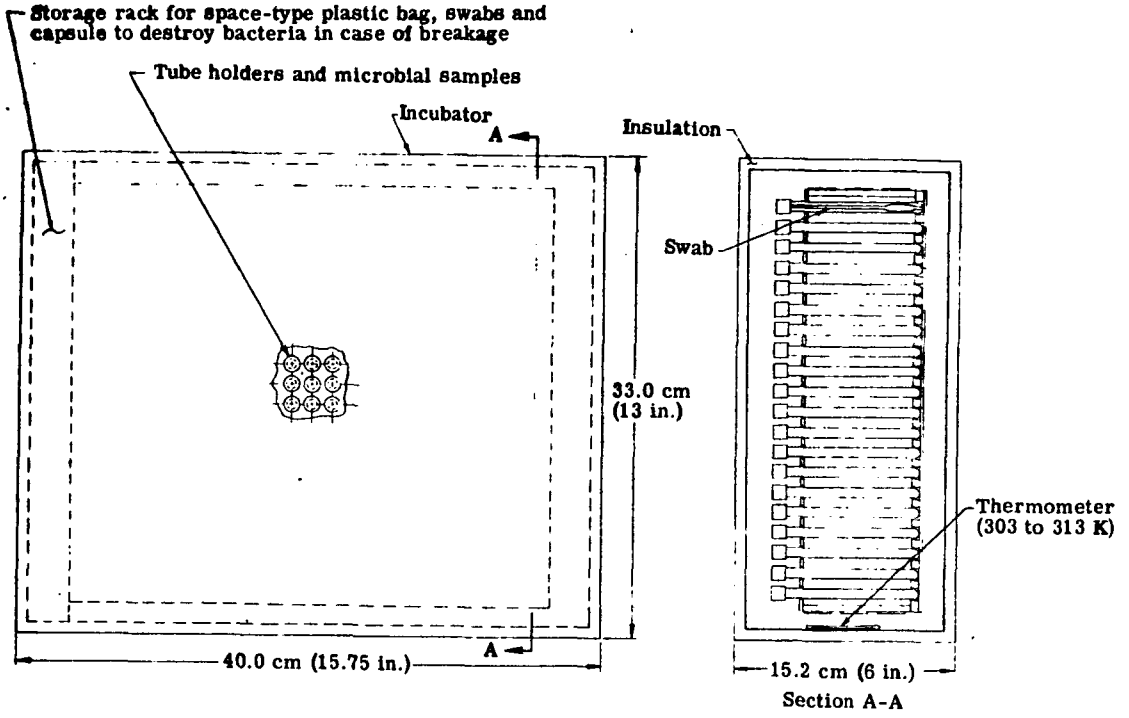


Figure C-40. Microbiological Sample Storage System

Experiment Operation Requirements

Observation duration: 0.25 hour per cycle
Total cycle time: 0.25 hour

Crew Requirements. Two general technicians each for 0.25 hour each day. Total support required for the mission is 3.5 hours.

EVA Activity. None

Crew Functions. Collect, incubate and store samples. A log is to be maintained of crewmen working in close proximity and contacting one another when these working periods exceed a few minutes. Crew is also to destroy samples in the event of breakage.

Consumables. None

Environmental Requirements. MB-2 (XST021)

Operational Status	Temperature (°K)	Relative Humidity (%)	Cleanliness (Class)	Acoustics (dB)	Acceleration (g)
OPERATING					
Internal Equip.	295 ± 5	55 ± 25	300,000	60	0.001
External Equip.					
NON-OPERATING					
Internal Equip.	295 ± 20	50 ± 45	300,000	145	9.0
External Equip.	283 ± 83		300,000	145	9.0

Development Status. The preflight development of the experiment hardware is minimal. This experiment is closely related to the Sampling of Airborne Particles and Micro-Organisms experiment. This investigation is an extension of current ground-based experimentation.

EXPERIMENT MB-3 (XST022)

Electrical Field Opacity in Biological Cells

Objective. The purpose of this experiment is to determine the electrical field opacity error involved in measuring cell volumes using ground-based electronic techniques.

Description. In ground laboratory work, extremely rapid measurements of cell volume can be performed with such electronic devices as the Coulter counter which senses local perturbations in a uniform electrical field caused by the cell. Electronic methods of this type, however, may be considerably in error due to the ionic permeability of cell membranes. Independent cell volume measurements are difficult because of sedimentation and attachment with subsequent changes in cell shape.

Long-term observations of suspended cell populations under weightless conditions will permit accurate cell volume measurements due to the spherical symmetry of the cell. Observations will be recorded on film by a time-lapse camera. Simultaneously, cell volume measurements of the same base culture will be made using an on-board Coulter counter. Results obtained by the Coulter counter will be recorded. Post-flight analysis of the results of both observation will permit the determination of the accuracy of the electronic measuring method.

The experiment requires that the cells be tested at 310 K, and at a pH between 7.0 and 7.3. At the completion of the test, the cells will be disposed of.

Approximately one hour will be required to perform the complete experiment, making both the time-lapse and the Coulter counter measurements.

The experiment equipment, shown in Figure C-41, includes a refrigerator, microscope, time-lapse camera, Coulter counter and printer, incubator, and volume spectrometer. Since the required equipment items have been extensively used in ground laboratories, and a microscope-camera included in Skylab, no major new development requirements are foreseen.

Pointing and Stability. Not applicable

Field of View. Not applicable

Mission Operation. The experiment is to be performed once throughout the mission. Approximately one hour is required to perform the complete experiment, making both time-lapsed and Coulter counter measurement. The acceleration is to be limited to 10^{-3}g during operation.

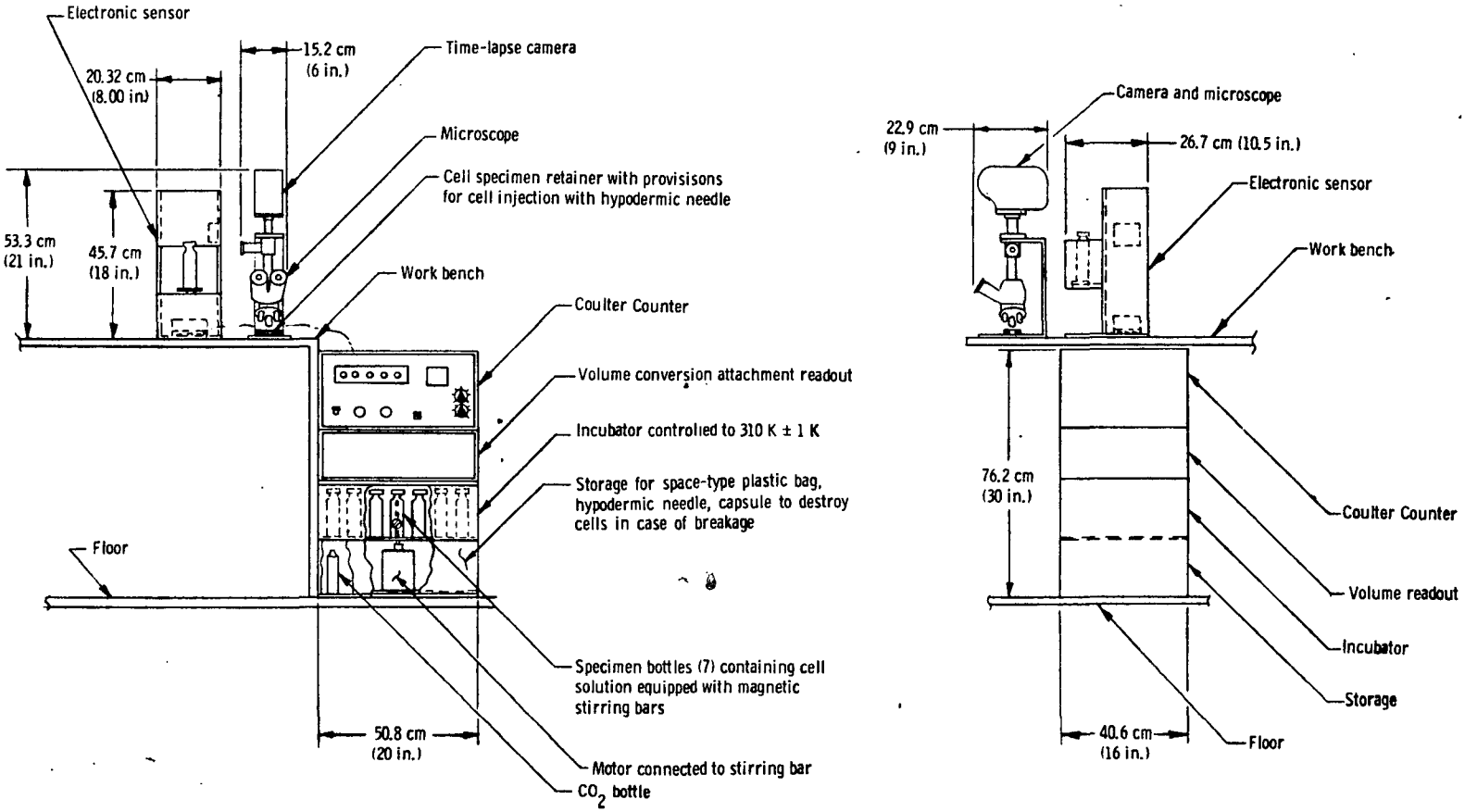


Figure C-41. Equipment for Electrical Field Opacity Experiment

EVA Activity. None

Crew Requirements. One photo technician for one hour (total).

Consumables

Film: 5 lb, 0.1 ft^3
Magnetic tape:
Cryogenics: None

Equipment		Qty	Location	Size (ft)			Vol. (ft^3)	Weight (lb)
Ref No.	Name			W/dia	H	L		
ST080	Refrigerator	1	Internal	3.0	2.0	1.0	6.0	30
ST083	Incubator	1	Internal	1.69	0.5	2.16	1.82	30
ST084	Coulter counter	1	Internal	1.69	1.0	2.16	3.65	20
ST085	Volume spectr.	1	Internal	1.69	0.5	2.16	1.82	15
ST086	Storage area	1	Internal	1.69	0.5	2.16	1.82	25
ST087	Camera-microscope	1	Internal	0.5	1.75	0.75	0.66	15
ST266	Electronic sensor	1	Internal	0.67	1.5	0.86	0.84	20

Configuration. See Figure C-41.

Electrical/Data Requirements. MB-3 (XST022)

Equipment		Power (watts)		Data	
Ref. No.	Name	Standby	Operate	Form	Rate
ST080	Refrigerator	-	60	-	-
ST083	Incubator	-	50	-	-
ST084	Coulter counter	-	75		
ST085	Volume spectrometer	-	50		
ST086	Storage area	-	-	-	-
ST087	Camera-microscope	0	10	Film	-
ST266	Electronic sensor		30	Display	

Environmental Requirements. MB-3 (XST022)

Operational Status	Temperature (°K)	Relative Humidity (%)	Cleanliness (Class)	Acoustics (dB)	Acceleration (g)
OPERATING					
Internal Equip.	295 ± 5	55 ± 25	300,000	60	0.001
External Equip.					
NON-OPERATING					
Internal Equip.	295 ± 20	50 ± 45	300,000	145	9.0
External Equip.	283 ± 83		300,000	145	9.0

Development Status. No major new development requirements are envisioned since the required equipment items have been extensively used previously.

EXPERIMENT MB-4 (XST023)

Electrical Characteristics of Cells

Objective. The objectives of the electrical characteristics experiment are to measure the electrophoretic mobility, surface zeta potential, and surface charge density of selected mammalian cell lines over the life cycles of the cells while under weightless conditions. The experiment will also investigate electrophoretic methods which take advantage of a weightless environment to determine electrical characteristics of cells.

Description. The surface properties of the cell are intimately involved in the process of cell division. Accurate measurement of these properties over the entire life cycle of the cell--especially during the division period--would result in a much clearer understanding of the role of electrical charges in division control. At present, our entire understanding of the electrical properties, however, is adversely affected by convection currents and cell sedimentation under gravitational forces. Consequently, cells can only be observed for short periods of time.

In the weightless environment, the convection and sedimentation effects are eliminated, thereby permitting very accurate measurement of the cells' electrical characteristics. It also permits the detection of very small differences in surface charge densities.

There are two separate steps involved in the operation of this experiment. The first is the preparation of the cultures to be observed. This consists of growing various cell lines in an artificial nutrient media and treating them with a 5-aminouracil (5-AU) chemical to arrest their growth and synchronize the cell population at a known point in the life cycle.

The second step is the measurement of the cellular electrophoretic mobility. This involves removing the growth-inhibiting chemical from the culture,

placing small volumes of the suspended cell culture in the electrophoretic apparatus at selected times, and determining both the cell size and mobility of individual cells in a known electric field. Those data are recorded by the operator for post-flight analysis.

Fifteen-minute observations every two hours during each cellular life cycle are envisioned. At the completion of the test, the cells are disposed of. Post-flight analysis of the data will determine the cell potential and charge as a function of time in the life cycle. The experiment is to be performed with the cells at 310 K and the pH between 7.0 and 7.3.

Physical Parameters. MB-4 (XST023)

Equipment		Qty	Location	Size (ft)			Vol. (ft^3)	Weight (lb)
Ref No.	Name			W/dia	H	L		
ST080	Refrigerator	1	Internal	3.0	2.0	1.0	6.0	30
ST083	Incubator	1	Internal	1.69	0.5	2.16	1.82	30
ST087	Camera-microscope	1	Internal	0.5	1.75	0.75	0.66	15
ST088	Electrophoretic apparatus	1	Internal	1.0	1.0	1.0	1.0	50
ST089	Culture ware*	1	Internal	0.5	0.5	1.0	0.25	5
ST090	Centrifuge	1	Internal	1.0	0.51		0.4	40

*Inside incubator (ST083)

Configuration. Not available.

Electrical/Data Requirements. MB-4 (XST023)

Equipment		Power (watts)		Data	
Ref. No.	Name	Standby	Operate	Form	Rate
ST080	Refrigerator	-	60	-	-
ST083	Incubator	-	50	-	-
ST087	Camera-microscope	0	10	Film	-
ST088	Electrophoretic apparatus	-	200	-	-
ST089	Culture ware	-	-	-	-
ST090	Centrifuge	-	50	-	-

Pointing and Stability. Not applicable

Field of View. Not applicable

Mission Operation. This experiment may be performed in any Shuttle orbit. Only one 20-hour experiment operation cycle is required throughout the mission. It is estimated that 15 minutes of observation every 2 hours throughout the operation cycle is adequate. At the completion of the experiment, the cells are disposed of.

This experiment may be adversely affected by strong electric or magnetic fields, sudden changes in acceleration level, and cyclic vibration of the test apparatus. Preliminary estimates indicate that acceleration levels should not exceed 10^{-3}g.

EVA Activity. None

Crew Functions. Maintaining growth of the cell lines; preparation of synchronized cultures by the application of 5 AU; placing cultures in the electrophoretic apparatus; periodic sampling and recording of data over the cell life cycle; and the securing of equipment for return flight, plus disposition of the cell at the termination of the experiment. Tasks also include disposing the cells throughout the experiment in the event of breakage.

Consumables. None

Environmental Requirements. *MB-4 (XST023)*

Operational Status	Temperature (°K)	Relative Humidity (%)	Cleanliness (Class)	Acoustics (dB)	Acceleration (g)
OPERATING					
Internal Equip.	295 ±5	55 ± 25	300,000	60	0.001
External Equip.					
NON-OPERATING					
Internal Equip.	295 ± 20	50 ± 45	300,000	145	9.0
External Equip.	283 ± 83		300,000	145	9.0

Development Status. The key element, the electrophoretic apparatus, has been extensively used in ground laboratories and a flight unit developed for Skylab. Consequently, no large development requirements are envisioned.

EXPERIMENT MB-5 (XST024)

Special Properties of Biological Cells

Objective. The purpose of this experiment is to determine the physical properties of human and mammalian cells under conditions of weightlessness.

Description. The properties to be studied in this experiment are cellular shape variations, cellular volume changes, cellular spreading and attachment, cell locomotion, cell-to-cell adhesion, cell surface molecular properties, serum sedimentation, all clones and clonal growth, slime-mold morphogenesis, and molecular basis of geotropism. Many of these characteristics and activities of human and mammalian cells cannot be accurately or meaningfully studied on earth because of the significant interference of gravity or gravity-related effects such as convectivity and sedimentation. Study of such activities under the conditions of weightlessness will potentially provide a greatly increased accuracy of measurement as well as elucidation of specific phenomena not otherwise observable.

Several very important biological phenomena, particularly those involved in the fundamental processes of morphogenesis, involve geotropism. Study of such processes under weightlessness can yield crucial and otherwise unattainable information as to the basic mechanisms of their functional and morphological involvements in response to gravity. All tests are to be performed with the cells at 310 K and at a pH between 7.0 and 7.3. At the completion of the experiment, disposition of cells is made. All the studies use time-lapse micrography to observe and record the cells under study.

Physical Parameters. MB-5 (XST024)

Equipment		Qty	Location	Size (ft)			Vol.	Weight
Ref. No.				W/dia	H	L	(ft^3)	(lb)
ST080	Refrigerator	1	Internal	3.0	2.0	1.0	6.0	30
ST083	Incubator	1	Internal	1.69	0.5	2.16	1.82	30
ST087	Camera-microscope	1	Internal	0.5	1.75	0.75	0.65	15
ST089	Culture ware	1	Internal	0.5	0.5	1.0	0.25	5

Configuration. Not available.

Electrical/Data Requirements. MB-5 (XST024)

Equipment		Power (watts)		Data	
Ref. No.	Name	Standby	Operate	Form	Rate
ST080	Refrigerator	-	60	-	-
ST083	Incubator	-	50	-	-
ST087	Camera-microscope	0	10	-	-
ST089	Culture ware	-	-	-	-

Pointing and Stability. Not applicable.

Field of View. Not applicable.

Mission Operations. This experiment may be operated in any Shuttle orbit. All studies can be performed in 5 days with 2 to 4 hours of operation each day. Operation of the time-lapsed camera is fully automatic. It is anticipated that all cultures will be premixed and readily available. The experiment is to be performed once per day and 5 times per mission.

EVA Activity. None

Crew Functions. Prepare various cell and organism samples for viewing in the time-lapsed unit by removing small populations from a central culture container, load time-lapse camera, turn camera on at the start of the experiment, maintain reasonable focus on the cell system under study, and remove film at completion of standby.

Consumables

Film: 5 lb, 0.1 ft^3
Magnetic tape:
Cryogenics: None

Environmental Requirements. MB-5 (XST024)

Operational Status	Temp. (°K)	Rel. Hum. (%)	Cleanliness (Class)	Acoustics (dB)	Acceleration (g)
OPERATING					
Internal Equipment	295 ± 5	55 ± 25	300,000	60	0.001
External Equipment					
NON-OPERATING					
Internal Equipment	295 ± 20	50 ±45	300,000	145	9.0
External Equipment	283 ± 83		300,000	145	9.0

Development Status. Little development effort is anticipated since it may be possible to utilize the same overall equipment and instrumentation developed for Skylab Experiment S015, Effects of Zero-Gravity on Single Human Cells.

ENVIRONMENTAL EFFECTS

Three experiments have been identified in the area of environmental effects. These involve obtaining data on the space cabin environment, obtaining *in situ* data on material fatigue life characteristics and fatigue crack propagation, and also obtaining *in situ* data of the space environment effects on non-metallic materials.

EXPERIMENT EN-1 (XST027)

Sampling of Airborne Particles and Micro-Organisms in Space Cabin Environment

Objectives. The purpose of this experiment is to obtain samples of the space cabin environment during a manned earth orbital mission. These samples would be used to provide information on the following:

1. The types of micro-organisms present in the cabin air environment.
2. The quantification of these micro-organism types.
3. The rate of change of these micro-organism types with respect to operations of and in the spacecraft.
4. The types, quantity and rates of change of non-viable particles.
5. The origin of the non-viable particles.
6. The classification of both viable and non-viable particles as to size.

Description. The generation and suspension of both viable and non-viable particles are increased in a weightless environment. These particles can cause two types of adverse effects in spacecraft cabin environments. One is a degradation of the reliability of spacecraft systems and subsystems, primarily those utilizing optical components. The other is the adverse effects of these particles on the health of the astronauts. In order to design contamination control equipment for the cabin environment, the sources, concentration and nature of these particles must be determined. The results of this experiment will be of value in verifying the theoretical predictions, evaluating ground test data, and designing the contamination control subsystems of future environmental control and life support systems. It will also provide data on the operation of the ATL contamination control system.

The experiment involves the periodic collection of air samples from both the ATL and the Shuttle cockpit area. The basic instruments consist of two air-sampling units, each unit containing two manifolded six-stage seive-type samplers. Cabin air is drawn into the units by pumps and the microflora and particulate matter are collected on surfaces in the units for post-flight analysis.

To collect data on the ATL environment, one sampler in the unit is run for one hour early in the mission and then turned off. The second sampler

in that unit is run for one hour late in the mission and then turned off. Data for the Shuttle area are obtained in a similar fashion. One sampler in the Shuttle unit is run for one hour during orbit insertion; the second for one hour during reentry. Should an in-flight emergency occur whereby particulate matter is introduced into either the ATL or Shuttle cockpit environment, the appropriate sampling unit will be turned on to obtain an air sample for emergency operations analysis. The experiment operation is highly automated requiring only that a crewman remove and store portions of the two units in a 278 K refrigerator after each sample is obtained. This experiment does not require data recording or data transmission during the mission.

Physical Parameters. EN-1 (XST027)

Equipment		Qty	Location	Size (ft)			Vol. (ft^3)	Weight (lb)
Ref No.	Name			W/dia	H	L		
ST080	Refrigerator	1	Internal	3.0	2.0	1.0	6.0	30
ST105	Air sample unit	1	Internal	1.0	1.0	0.5	0.5	15
ST105	Air sample unit	1	Orbiter cabin	1.0	1.0	0.5	0.5	15
ST106	C/D console	1	Internal	0.45	0.5	1.0	0.23	10
ST107	Timer	1	Internal	0.2	0.2	0.2	0.008	0.5

Configuration. Not available.

Electrical/Data Requirements. EN-1 (XST027)

Equipment		Power (watts)		Data	
Ref. No.	Name	Standby	Operate	Form	Rate
ST080	Refrigerator	-	60	-	-
ST105	Air sample unit	-	100	Sample	2/mission ea.
ST106	C/D console	0	20	-	-
ST107	Timer	-	5	Display	-

Pointing and Stability Requirements. None

Field of View. Not applicable

Mission Operations. Unit installed in ATL to be operated for one hour near the beginning of mission, and for one hour near the end of mission. Unit in the Orbiter cabin is to be operated for one hour during orbit insertion and for one hour during reentry. Appropriate sampling unit also to be operated in the event of an emergency such as a fire.

EVA Activity. None

Crew Function. Operate experiment equipment, remove and store samples in the refrigerator, and secure equipment for return flight.

Consumables. None

Environmental Requirements. EM-1 (EST027)

Operational Status	Temperature (°K)	Relative Humidity (%)	Cleanliness (Class)	Acoustics (dB)	Acceleration (g)
OPERATING					
Internal Equip.	295 ± 5	55 ± 25	300,000	60	0.001
External Equip.					
NON-OPERATING					
Internal Equip.	295 ± 20	55 ± 45	300,000	145	9.0
External Equip.	283 ± 83		300,000	145	9.0

Development Status. Air sampler technology is well advanced and no large development effort is anticipated. Some modification to existing designs may be required, along with flight-qualification testing.

EXPERIMENT EN-2 (XST028)

Orbital Fatigue Experiment

Objective. The purpose of this experiment is to obtain *in situ* data on the effects of the space environment on material fatigue life characteristics and fatigue crack propagation.

Description. Results of laboratory fatigue tests on 7075-T6 aluminum-alloy specimens conducted in a vacuum chamber indicated that for a given stress level, the lower the air pressure the longer the fatigue life. Since the gas species in the chamber differ from those in space, however, this increase in fatigue resistance may not be realized in the space environment. This experiment will provide *in situ* test data to establish the validity of ground-laboratory results and to develop revised ground test procedures and data evaluation techniques where required.

The experiment equipment is illustrated in Figure C-42. The experiment is to be conducted in two parts.

1. FATIGUE LIFE TEST. A test sample is mounted in the test machine in the airlock and the test load is set. The fatigue test machine and sample are then deployed to the space environment and the fatigue testing is initiated. Accumulated cycles and load are displayed on an internal console. The test continues until the sample fails, at which time the machine automatically shuts down. The assembly is retrieved, the sample replaced, and the test repeated.

2. CRACK PROPAGATION TEST. The test procedure is the same as that for the fatigue life experiment, except the test specimens are instrumented with break wires to indicate crack propagation with the number of load cycles. Additional equipment is required inside the module to monitor the break wire circuits until the test specimen fails, and to record the data.

An airlock is required to deploy the fatigue-testing machine into the space environment. Problems associated with the effects of temperature gradients and contamination of the fatigue test machine and test specimens are yet to be resolved. The solution to these items may influence the orbital attitude and the deployment requirements.

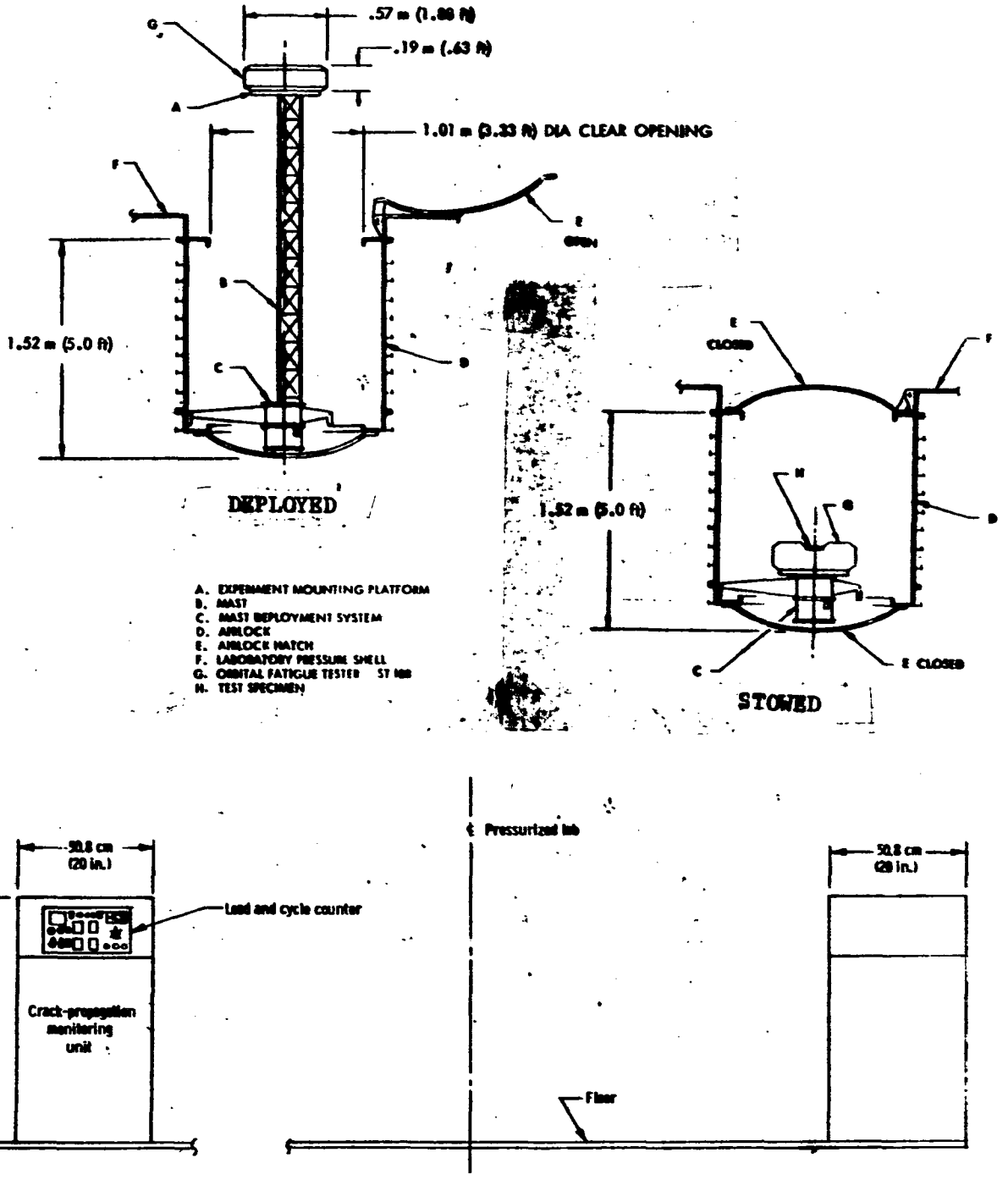


Figure C-42. Equipment Layout for Orbital Fatigue Experiment

Physical Parameters. EN-2 (XST-028)

Equipment		Qty	Location	Size (ft)			Vol. (ft^3)	Weight (lb)
Ref No.	Name			W/dia	H	L		
ST008	Tape recorder	1	Internal	1.6	0.9	1.6	2.3	100
ST078	Airlock*	1	-	-	-	-	-	-
ST108	Fatigue tester	1	Airlock	1.9	-	0.62	1.75	100
ST109	Load/cycle counter	1	Airlock	0.9	0.9	1.66	1.34	20
ST111	Crack propagation monitor	1	Airlock	1.7	2.1	1.7	6.1	50
ST244	Mounting plate/ extension mech.	1	Airlock	3.0	1.5**	-	10.6	50
ST269	Fatigue specimen	10	Airlock	0.3	0.3	0.03	.0027	0.1

*Included as part of sortie laboratory
**Stowed height; deploys (TBD) feet.

Configuration. See Figure C-42.

Electrical/Data Requirements. EN-2 (XST028)

Equipment		Power (watts)		Data	
Ref. No.	Name	Standby	Operate	Form	Rate
ST008	Tape recorder	25	250	D	-
ST078	Airlock	-	-	-	-
ST108	Fatigue tester	-	200	-	-
ST109	Load/cycle counter	-	50	D	500 bps
ST111	Crack monitor	-	50	D	500 bps
ST244	Mounting plate	-	50	-	-
ST269	Fatigue specimen	-	-	-	-

Pointing and Stability Requirements. None

Field of View. Not applicable

Mission Operation. The experiment is to be performed from a preferred altitude of about 250 nmi. Attitude requirements may develop later due to the solution of temperature gradient studies.

EVA Activity. None

Crew Functions. Install test samples in the fatigue test machine; set sample test load; deploy test machine; initiate test, retrieve test machine at the conclusion of the test; and record data.

Consumables

Magnetic tape: 10 lb, 0.2 ft^3
Sample specimens: 20 lb, 0.6 ft^3
Cryogenics: None
Film: None

Environmental Requirements. *EN-2 (XST028)*

Operational Status	Temperature (°K)	Relative Humidity (%)	Cleanliness (Class)	Acoustics (dB)	Acceleration (g)
OPERATING					
Internal Equip.	295 ± 5	55 ± 25	300,000	60	0.001
External Equip.					
NON-OPERATING					
Internal Equip.	295 ± 20	55 ± 45	300,000	145	9.0
External Equip.	283 ± 83		300,000	145	9.0

Development Status. A prototype fatigue test machine is presently being designed and fabricated by the Lockheed (California) Corporation.

EXPERIMENT EN-3 (XST029)

Environmental Effects on Non-Metallic Materials

Objective. The purpose of this experiment is to collect *in situ* data on the effects of the near-earth space environment on elastomers, coatings, and polymeric films.

Description. Ground tests have shown that many non-metallic materials exhibit changes in optical and mechanical properties after a relatively short exposure time to simulated space environment. These tests, however, are limited in their capability to provide a real-time simulation of the degrading elements of the space environment. The data obtained from this experiment will be utilized to evaluate the suitability of non-metallic materials for space applications as well as improving laboratory simulations of space environmental effects.

The experiment consists of two arrays of samples sealed within vacuum-tight containers. The configuration is shown in Figure C-43. Upon test initiation, both arrays are deployed by a single extendable boom. With the boom fully extended, the samples are unsealed and exposed to the space environment by mechanically removing covers from the array containers. The array will be positioned to obtain the maximum sunlight possible without active solar orientation. During the mission the experiment is completely passive. Prior to reentry, the array containers are resealed, the boom retracted, and the samples maintained in vacuum storage until delivery to the ground laboratory for analysis. Since exposure to oxygen can eliminate the effects of radiation on many of these materials, the integrity of the vacuum seal on these canisters is essential to the successful completion of this experiment.

Physical Parameters. EN-3 (XST029)

Equipment		Qty	Location	Size (ft)			Vol. (ft^3)	Weight (lb)
Ref No.	Name			W/dia	H	L		
ST008	Tape recorder	1	Internal	1.6	0.9	1.6	2.3	100
ST042	Deploy/retract system*	1	External	0.33	1.41	2.2	1.02	25
ST112	Sample arrays	4	External	0.6	0.2	0.6	0.07	0.5
ST113	Vacuum containers	4	External	0.6	0.2	0.6	0.07	5
ST241	Tray cover motor	1	External	0.4	-	0.4	0.05	2
ST242	Sun sensor	1	External	0.1	0.1	0.7	0.007	0.5

*Boom deploys approximately 50 feet.

Configuration. See Figure C-43.

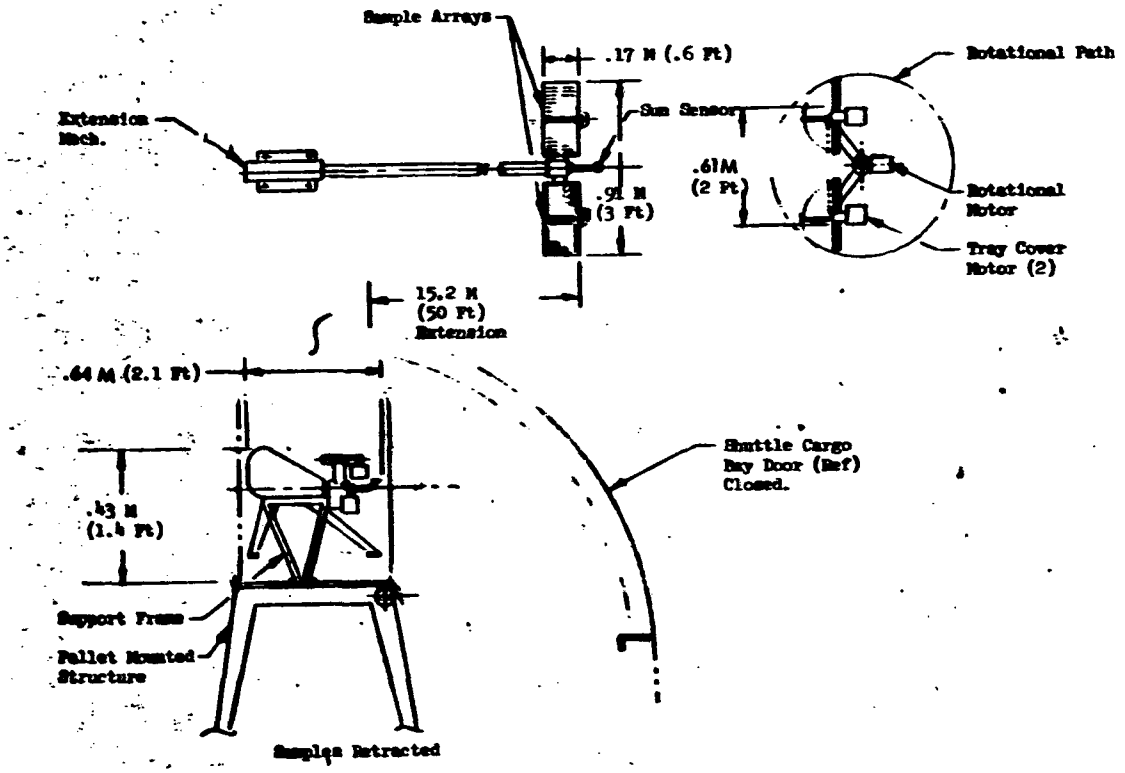


Figure C-43. Non-Metallic Material Degradation Experiment

Electrical/Data Requirements. EN-3 (XST029)

Equipment		Power (watts)		Data	
Ref. No.	Name	Standby	Operate	Form	Rate
ST008	Tape recorder	25	250	D	-
ST042	Deploy/retract sys	-	75	-	-
ST112	Sample arrays	0	75	D	500 bps
ST113	Vacuum containers	-	-	-	-
ST241	Tray cover motor	-	75	-	-
ST242	Sun sensor	-	5	-	-

Pointing and Stability Requirements. None

Field of View. Not applicable

Mission Operation. Continuous exposure of the samples is desired after initial deployment. Diagnostic data require periodic readout of one temperature on each array at specific points during the mission.

EVA Activity. None

Crew Functions. Activation of extension and sample exposure mechanism at the start of the experiment; activation of the sample resealing and retraction mechanisms at the end of the experiment.

Consumables

Magnetic tape: 10 lb, 0.2 ft^3
Film: None
Cryogenics: None

Environmental Requirements. EN-3 (XST029)

Operational Status	Temperature (°K)	Relative Humidity (%)	Cleanliness (Class)	Acoustics (dB)	Acceleration (g)
OPERATING					
Internal Equip.	295 ± 5	55 ± 25	300,000	60	0.001
External Equip.					
NON-OPERATING					
Internal Equip.	295 ± 20	55 ± 45	300,000	145	9.0
External Equip.	283 ± 83		300,000	145	9.0

Development Status. It is anticipated that the design and development will be straightforward. The effects of external contamination require further analysis.

Two experiments have been identified in the area of component and system testing; both experiments are related to spacecraft systems verification. One experiment evaluates operation of a steam generator in zero-gravity environment and the other is a contamination monitor.

EXPERIMENT CS-2 (XST026)

Zero-Gravity Steam Generator

Objective. The purpose of this experiment is to obtain steam generator performance data under operation at near-zero gravity levels in earth orbit.

Description. A promising technique for removing CO_2 from the cabin air is steam desorption which utilizes steam to display CO_2 from the sorbent beds in the system. The phase change and heat transfer processes involved in the steam generator, however, are expected to be gravity-sensitive. At reduced gravity levels, performance parameters such as amount of steam generated and steam quality are difficult to predict analytically or to simulate with ground tests. The steam generator performance data obtained in this experiment will be of value in verifying analytical performance prediction methods as well as for design applications.

The configuration of the steam generator is shown in Figures C-44 and C-45. Input water is circulated through channels running from the outer surface to the hot central heat source wherein a silicon fluid is continuously circulated at 394 K to 422 K. Near the center of the generator coil, the water turns to steam and the steam is drawn off through another flow channel. Supporting equipment includes a water supply system, a steam/water recovery system, a liquid heat loop, a control and display panel and a tape recorder. A block diagram of the experiment is shown in Figure C-46.

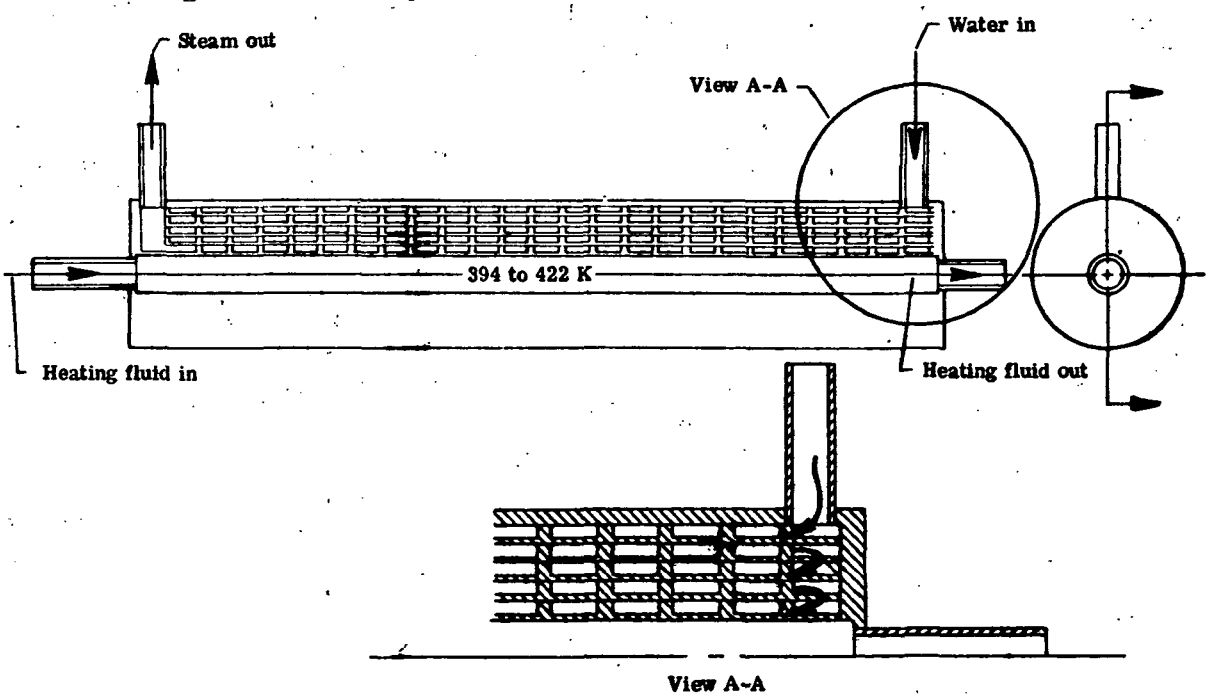


Figure C-44. Zero-Gravity Steam Generator Concept

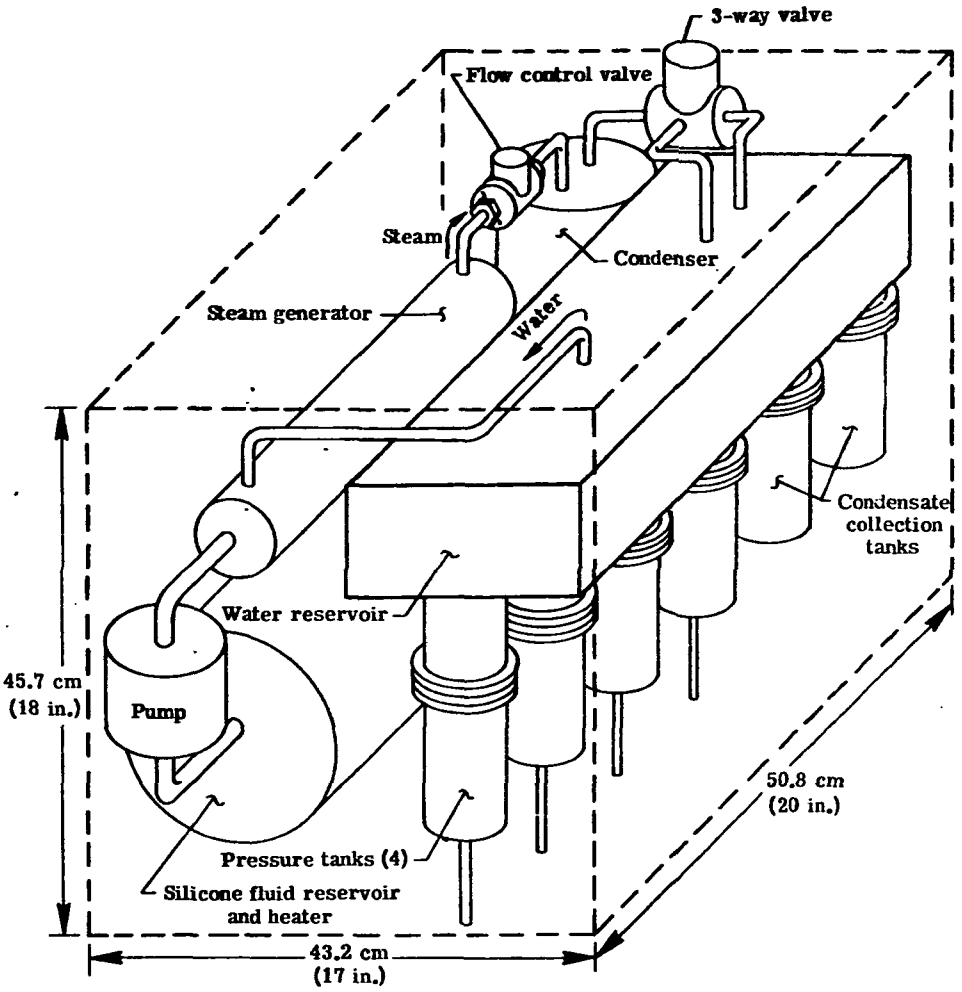


Figure C-45. Equipment Layout for Zero-G Steam Generator Experiment

Total volume, 0.099 m^3 (3.5 ft^3)

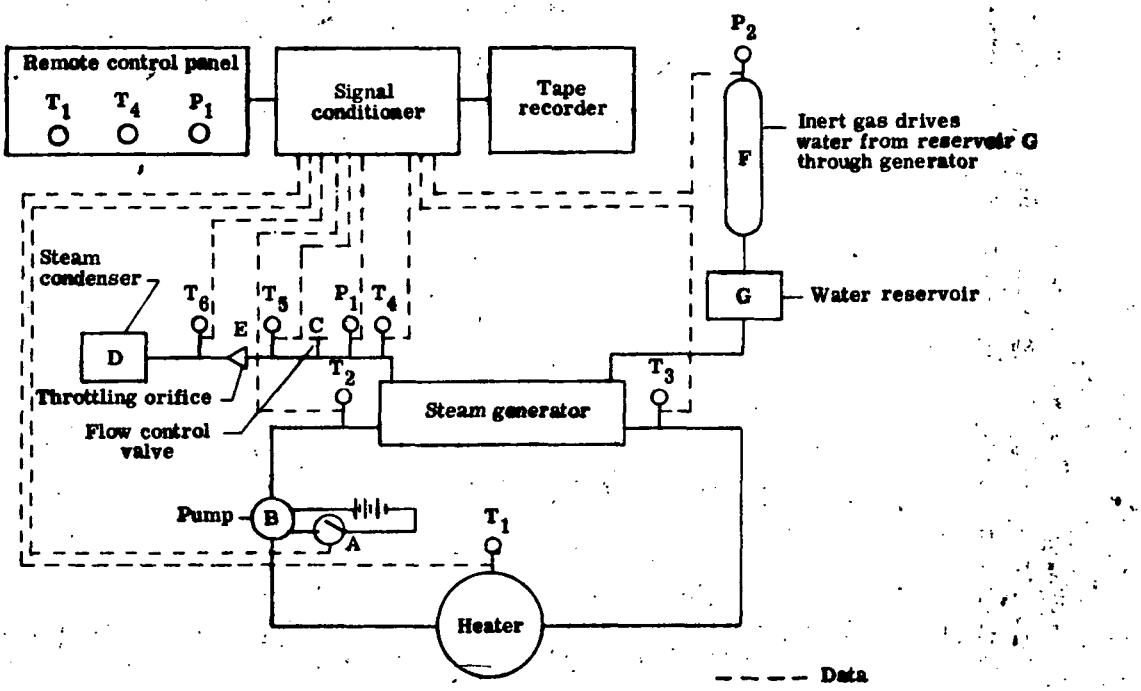


Figure C-46. Block Diagram of Zero-G Steam Generator Experiment

(Note. All data must be recorded plus T_1, T_4, and P_1 displayed visually on remote control panel.)

Physical Parameters. CS-2 (XST026)

Equipment		Qty	Location	Size (ft)			Vol. (ft^3)	Weight (lb)
Ref No.	Name			W/dia	H	L		
ST008	Tape recorder	1	Internal	1.6	0.9	1.6	2.3	100
ST098	Pressure tank	4	Internal				*	*
ST099	Water reservoir/ heater	1	Internal				*	*
ST100	Steam generator	1	Internal				*	*
ST101	Pump	1	Internal				*	*
ST102	Steam condensor	1	Internal				*	*
ST103	Electronics	1	Internal	1.0	0.5	0.5	0.25	10
ST104	C/D console	1	Internal	1.6	3.0	2.0	9.6	85
ST285	Hardware flow circuits	1	Internal				*	*
	Steam generator rack	1	Internal	1.4	1.5	1.66	3.48	114

*Integrated into a single steam generator rack

Configuration. See Figures C-44 and C-45.

Electrical/Data Requirements. CS-2 (XST026)

Equipment		Power (watts)		Data	
Ref. No.	Name	Standby	Operate	Form	Rate
ST008	Tape recorder	25	250	D	-
ST103	Electronics	-	10	-	-
ST104	C/D console	-	20	-	-
	Steam generator rack	-	500	D	3 kbps

Pointing and Stability. Not applicable.

Field of View. Not applicable

Mission Operation. The experiment is to be operated for two test runs. There is to be one observation per day for two days.

Crew Functions. Operate switches and valves. Monitor displays.

Consumables. Magnetic tape

Environmental Requirements. CS-2 (XST026)

Operational Status	Temperature (°K)	Relative Humidity (%)	Cleanliness (Class)	Acoustics (dB)	Acceleration (g)
OPERATING					
Internal Equip.	295 ± 5	55 ± 25	300,000	60	0.001
External Equip.					
NON-OPERATING					
Internal Equip.	295 ± 20	55 ± 45	300,000	145	9.0
External Equip.	283 ± 83		300,000	145	9.0

Development Status. Prototype hardware currently being evaluated. No significant development problems are anticipated.

EXPERIMENT (XST-)

Contamination Monitor

Objective. The purpose of this experiment is to monitor the type and level of contamination in the Orbiter cargo bay.

Description. This experiment consists of a series of passive sensors mounted in the Orbiter cargo bay to monitor the contamination of different points throughout the mission. It is anticipated that groups of sensors will be sequentially exposed to the Orbiter bay environment. The phases of the mission at which the contamination monitoring is desired are: booster ignition, Orbiter main engine ignition, orbit, deorbit, and landing rollout.

Physical Parameters. TBD

Configuration. Not available.

Electrical/Data Requirements. TBD

Pointing and Stability Requirements. None

Field of View. Not applicable

Mission Operations. The sensors mounted in the Orbiter cargo bay are exposed to the environment at five different phases of the mission.

Experiment Operational Requirements. TBD

Crew Requirements. One general technician for TBD hours per day, and TBD hours per mission.

EVA Activity. None

Crew Function. Activation of exposure and resealing mechanism.

Consumables

Magnetic tape: TBD
Sample specimens: TBD
Film: None
Cryogenics: None

Environmental Requirements.

Operational Status	Temperature (°K)	Relative Humidity (%)	Cleanliness (Class)	Acoustics (dB)	Acceleration (g)
OPERATING					
Internal Equip.	295 ± 5	55 ± 25	300,000	60	0.001
External Equip.					
NON-OPERATING					
Internal Equip.	295 ± 20	55 ± 45	300,000	145	9.0
External Equip.	283 ± 83		300,000	145	9.0

Development Status. Experimental

APPENDIX D

D. ACTIVITY DATA SHEETS

APPENDIX D. ACTIVITY DATA SHEETS

Appendix D contains the activity data sheets (ADS) for both the complete Spacelab (Part I) and the pallet-only (Part 2) configurations. These activity data sheets are detailed definitions of the test operations associated with each activity that is defined in the expanded functional blocks (Volume II, Section 4.2). Each sheet contains an activity identification section which lists the related functional flow number, the title, and the applicable concepts where this activity is utilized. It also references the principal Spacelab hardware elements that are involved. The second part of the ADS is the description section where a detailed identification of the operations involved and the time estimates and resources required to accomplish the task are defined. With each activity data sheet, there is a detailed functional flow. These flows illustrate the composite time sequence for that specific ground processing operation.

Utilizing the resource requirements and time sequencing of operations from the activity data sheets, the determination of GSE, facility and T&O personnel will be facilitated. These data sheets can also be used to establish the sensitivity of the concepts to varying flight rates.

PART 1. COMPLETE SPACELAB

To assist in the correlation of these activity data sheets to the referenced applicable concept, Table D-1 has been included.

Table D-1. Complete Spacelab Processing Concepts

Concept Number	Owner			Integration Site	
	Support Module	Experiment Module	Pallet	Experiment Equipment	Spacelab
I	IC	IC	IC	IC	IC
II	LS	IC	IC	IC	LS
III	LS	IC	IC	User	LS
IV	LS	User	User	User	LS
V	User	User	User	User	User

In order to cross-correlate these activities and the appropriate detailed flows to which they relate, this information must be referenced back to Volume II, Section 4.2.

BLOCK 1.0 EXPERIMENT TRANSPORATION

*******1*******2 WORKING DAYS

**** TRANSFER EXPERIMENTS FROM USER/PI LAB TO EXPMT INTEGRATION AREA
**** CONDUCT EXERIMENT RECIEVING INSPECTION

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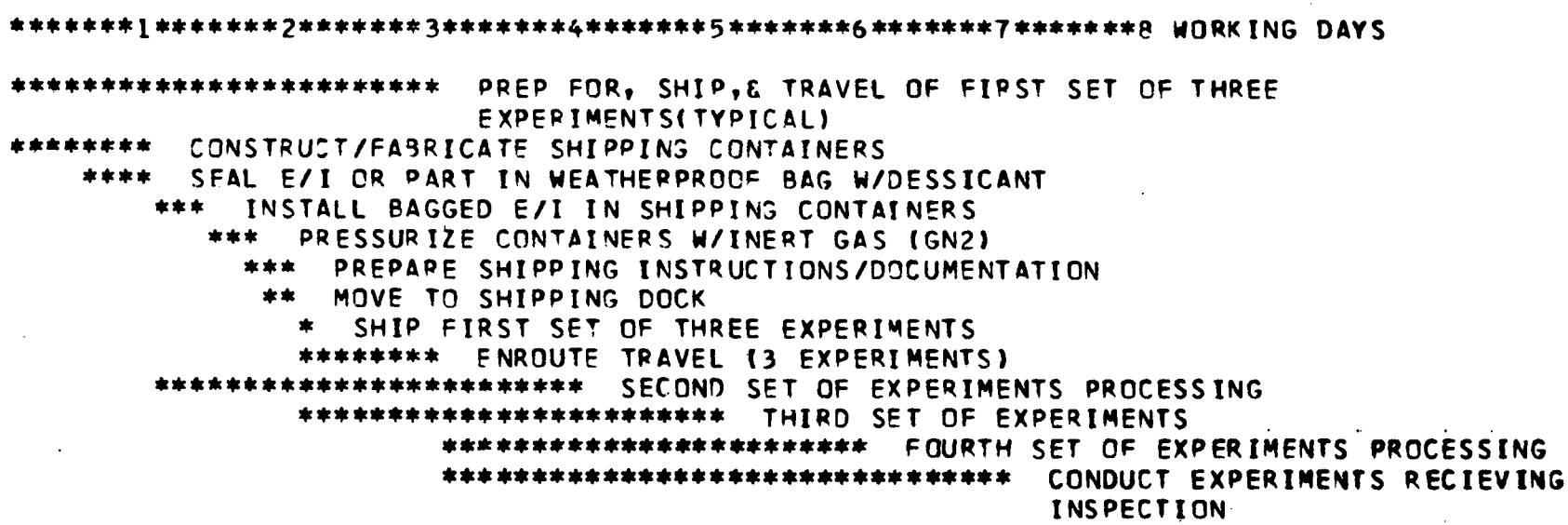
BLOCK 1.0 EXPERIMENT SHIPMENT



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ACTIVITY DATA SHEET

1.0 ACTIVITY IDENTIFICATION

Functional Flow Number: 1.0 Applicable Concepts: ALL

Title: Experiment Shipment

Principal Elements: Experiments and Experiment Racks

2.0 ACTIVITY DESCRIPTION

This activity is concerned with the transportation and shipment of experiments and experiment-related racks and auxiliary equipment from its initial deployment from the principal investigator (PI) and subsequent return; or from the user to other centers and return. It is specifically pertinent to the geographical relocation of equipment as differentiated from localized movement within a given center.

The activity deals with all preparations required in the shipment process, including initial construction of shipping containers, documentation, equipment installation, contamination control and container pressurization.

Responsibility for shipment and follow-up status belongs to the consignor, and represents the final action of this activity. The timeline for this task was based upon an average processing time of 3 experiments per day; considering processing time overlaps, shipping and receiving/inspection, the total timeline is 7 days for 12 experiments.

BLOCK 2.0 EXPERIMENT INSTALLATION

```
*********1*********2*********3*********4*********5 WORKING WEEKS

**********************  RACKS/EXPERIMENTS BUILDUP & PREINTEGRATION
                  ****  PREPARATIONS FOR EXPMT'S/RACKS,AFT BULKHEAD & AFT UTILITY BRIDGE
                        INSTALLATION
                     **********************  INSTALL EXPERIMENTS ON PALLET
                     **  NAVIGATION
                       ******  EARTH OBSERVATION
                             *  ENVIRONMENTAL EFFECTS
                              *  COMPONENTS AND SYSTEMS
                               *  MICROBIOLOGY
                                *********  PHYSICS AND CHEMISTRY
                     **************  INSTALL PRE-INTEGRATED RACKS/EXPMT'S ON EM STRUCTUAL
                                     FLOOR
                                   ******  INSTALL EM AFT BULKHEAD & AFT UTILITY BRIDGE
                                         *  VERIFY PLUGS OUT CONTINUITY OF ALL ELEC
                                            CONNECTORS
                                          ***  MATE ELEC/FLUID CONN & LK CK FLUID CONN AT
                                               AFT BLKHD & PALLET INTERFACES
                                         ****  PREPS FOR RACK/EXPMT'S/SM SIM SET MATE
```


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ACTIVITY DATA SHEET

1.0 ACTIVITY IDENTIFICATION

Functional Flow Number: 2.0 Applicable Concepts: ALL

Title: Experiment Installation

Principal Elements: Racks/Experiments, Experiment Module Floor and Aft Bulkhead, Aft Utility Bridge and Pallet

2.0 ACTIVITY DESCRIPTION

This task represents the beginning of Level III testing and includes buildup and pre-integration of racks/experiments, preparations and installation of racks/experiments, installation of the experiment module aft bulkhead and utility bridge. The requirement for the EM aft bulkhead at this stage is precipitated by the necessity for routing cables and connections from the racks/experiments on the experiment module floor, through a feed-through connection in the EM aft bulkhead, through the aft utility bridge, to experiments on the pallet. This operational procedure obviates the necessity for breaking connections between the racks/experiments in the EM with those on the pallet following experiment integration tests.

A plugs-out continuity test prior to connecting electrical interfaces, mate of electrical/mechanical interfaces, leak check of fluid lines/connections, and preparations for mating the support module simulator to the racks/experiments form a part of the activity of this task.

ACTIVITY DATA SHEET

1.0 ACTIVITY IDENTIFICATION

Functional Flow Number: 2.1 Applicable Concepts: ALL

Title: Racks/Experiments Buildup and Pre-Integration

Principal Elements: Racks/Experiments

2.0 ACTIVITY DESCRIPTION

This subtask is devoted to the buildup and pre-integration of experiments and racks prior to installation on the experiment module structural floor. This activity is the beginning of Level III testing and will require participation by the cognizant principal investigator (PI) during this period. Some PI-owned, experiment-unique checkout equipment will probably be required. The distinguishing feature of this stage of testing is that it will deal with single racks, not necessarily dedicated to a single experiment. Several PI's may be involved in the pre-integration of a single rack. The purpose of this pre-integration is to determine minor system discrepancies prior to installation when access may be a problem.

ACTIVITY DATA SHEET

1.0 ACTIVITY IDENTIFICATION

Functional Flow Number: 2.2 Applicable Concepts: ALL

Title: Preparation for Installation of Racks/Experiments

Principal Elements: EM Floor Structure, EM Aft Bulkhead and Aft Utility Bridge, Pallet and Racks/Experiments

2.0 ACTIVITY DESCRIPTION

This subtask covers the effort required to move/position the experiments/racks support structure, i.e., the experiment module (EM) floor structure and aft bulkhead, pallet and utility bridge, installation of external (GSE) lighting, gathering of equipment mounting brackets, racks, and attaching hardware and setup of alignment aids (transit/collimator) for experiments alignment to pallet. Prior to lifing pallet structure, this task will include proof-testing crane and lifting devices or verification that previous proof-test is still valid.

ACTIVITY DATA SHEET

1.0 ACTIVITY IDENTIFICATION

Functional Flow Number: 2.3 Applicable Concepts: ALL

Title: Install Experiments and Pre-Integrated Racks/Experiments

Principal Elements: EM Floor Structure, Pallet, EM Aft Bulkhead, Aft Utility Bridge and Racks/Experiments

2.0 ACTIVITY DESCRIPTION

This subtask provides for installation of racks/experiments on experiment module (EM) floor structure; installation and alignment of experiments on pallet; and routing of interconnecting cables and fluid lines up to interface connections. The installation of experiments on the pallet and racks/experiments on the EM floor structure are non-interfering and will be performed in parallel. Most of these installations probably can be made without heavy-duty lifting devices; however, some of the large pallet-mounted experiments will likely require an overhead traveling crane capability.

ACTIVITY DATA SHEET

1.0 ACTIVITY IDENTIFICATION

Functional Flow Number: 2.4 Applicable Concepts: ALL

Title: Install EM Aft Bulkhead and Aft Utility Bridge

Principal Elements: EM Floor Structure, Pallet, EM Aft Bulkhead, Aft Utility Bridge and Racks/Experiments

2.0 ACTIVITY DESCRIPTION

Following installation of racks and experiments, the experiment module (EM) aft bulkhead will be positioned at the aft end of the EM floor and the surface/seal protective cover removed. The bulkhead will require a GSE support or jury strut to rigidly secure it when not attached to the EM shell structure. Once the aft bulkhead is in place, cables/lines can be routed between the pallet/EM, through the bulkhead feedthrough and aft utility bridge. Connectors (electrical) will not be mated until after continuity checks have been made.

ACTIVITY DATA SHEET

1.0 ACTIVITY IDENTIFICATION

Functional Flow Number: 2.5 Applicable Concepts: ALL

Title: Plugs-Out Continuity Checks and Mate Electrical/Fluid Connections

Principal Elements: EM Floor Structure, Pallet, EM Aft Bulkhead, Aft Utility Bridge and Racks/Experiment

2.0 ACTIVITY DESCRIPTION

Prior to mating electrical connectors between pallet/experiment module (EM) experiments and equipment through the aft utility bridge, a pin-to-pin continuity check will be required. When proper continuity has been verified, all electrical and fluid connections will be made and torqued to design specifications. The aft utility bridge will be rigged to provide a non-binding routing for electrical/fluid cables/lines between pallet and EM. When all fluid connections have been made, preparations for fluid lines/connections leak checks can be started.

ACTIVITY DATA SHEET

1.0 ACTIVITY IDENTIFICATION

Functional Flow Number: 2.6 Applicable Concepts: ALL

Title: Leak-Check Fluid Lines and Connections, and Preparations for Service Module (SM) Interface Simulator Mate

Principal Elements: EM Floor Structure, Pallet, EM Aft Bulkhead, Aft Utility Bridge and Racks/Experiment

2.0 ACTIVITY DESCRIPTION

Following completion of all fluid line connections, a leak check will be required prior to servicing of fluid systems. While it is recognized that some fluid systems will require special considerations, generally it will be sufficient to pressurize or evacate systems to conduct leak checks. For positive pressures a low-pressure, inert, dry gas such as nitrogen is utilized. For vacuum leak checks, system lines are evacuated using a small vacuum pump. In either case, trace quantities of helium are then introduced into the systems and leak rates can be accurately assessed using a helium-sensitive mass sprectrometer.

Servicing of systems will be accomplished during support module interface simulator checkout prior to start of Level III experiment integration tests.

After leak checks have been made and fluid systems pressure integrity has been verified, preparations for mate with the SM interface simulator will begin. The checkout area will be cleaned up by removing all equipment not required for the up-coming experiment integration tests. Positioning of remaining equipment to accept the SM interface simulator will probably be necessary.

BLOCK 3.0 CONNECT SM INTERFACE SIMULATOR

```
*******1*******2*******3*******4*******5*******6*******7 WORKING DAYS

********  MOVE/POSITION SM INTERFACE SIM & SERVICING UNITS IN C/O AREA
         ********  VERIFY SM INTERFACE SM ELEC/MECH CONNECTIONS W/FACILITY INTERFACES
                  ****  CONNECT SM INTERFACE SIM & SERVICING UNITS TO FAC. INTERFACES
                  ****  VERIFY SM INTERFACE SIM/RACKS/EXPMT'S INTERFACES
                      **  CONNECT SM INTERFACE SIM , SERVICING UNITS TO RACKS/EXPMT'S
                          INTERFACES
                        **  PWR UP COOLANT LOOP SER. UNITS AND VERIFY FLD FLOW & CTRL THRU
                            SUT'S/R/EXPMT/P
                          **  PERFORM BUS ISOL TESTS OF R/EXPMT/P
                            **  CONDUCT PRE-PWR SW LIST TO VERIFY SW & CONTROL SETTINGS
                              *  PWR UP ELEC PORTION OF SM INTERFACE SIM-EXCLUDING IMS
                                 FUNCTIONS
                               **  CONDUCT PWR DISTR TESTS
                                 *  VERIFY CAUTION WARNING IND'S-PUSH TO TEST CIRCUIRTY
                                 *  PWR UP IMS PORTION OF SM INTERFACE SIM
                                  *  CONDUCT COMP & INSTR SELF CK'S
                                  ****  VERIFY IMS COMMAND/CONTROL
                                      *  VERIFY IMS PERIF EQUIP (PRINTERS, RECORDERS,
                                         PLOTTERS, ETC)
                                       *  VERIFY GND DATA BASE COMP VIA THE GDB ACESS CABLE
                                       *  VERIFY RACK/PALLET AUX EQUIP-CTTV, INTERCOM, ETC
                                        *  POWER DOWN ELEC/MECH SYS & ALL SERVICING EQUIP
                                        ********  CONDUCT EXPMT INTEG READINESS REVIEW (PI
                                                  PARTICIPATION)
```

Sheet 1 of 1

ACTIVITY DATA SHEET

1.0 ACTIVITY IDENTIFICATION

Functional Flow Number: 3.0 Applicable Concepts: ALL

Title: Connect Support Module (SM) Interface Simulator

Principal Elements: Pallet, Racks/Experiment, EM Floor Structure and Aft Bulkhead, Aft Utility Bridge, SM Interface Simulator and Servicing Units

2.0 ACTIVITY DESCRIPTION

The support module interface simulator is utilized to provide power, control and display, caution and warning, analog/video data, closed-circuit television (CCTV), intercommunications, data bus and experiment processor functions to the experiment module/pallet combination in the absence of an actual support module.

The activity of this task covers:

1. Emplacement and connection of the SM interface simulator and servicing GSE.
2. Power-up and checkout of the SM interface simulator and servicing equipment.
3. Support of the Experiments Integration Readiness Review with NASA.

ACTIVITY DATA SHEET

1.0 ACTIVITY IDENTIFICATION

Functional Flow Number: 3.1 Applicable Concepts: ALL

Title: Position and Connect SM Interface Simulator and Servicing Units

Principal Elements: Pallet, Racks/Experiment, EM Floor Structure and Aft Bulkhead, Aft Utility Bridge, SM Interface Simulator and Servicing Units

2.0 ACTIVITY DESCRIPTION

This subtask is comprised of the pre-mate preparations and physical connection of the SM interface simulator and servicing units to the racks/experiments/pallet. The following sequence of events is necessary to fully implement this subtask.

- Move/position SM interface simulator and servicing units in the checkout area.
- Verify SM interface simulator/servicing units facility interfaces.
- Connect simulator/servicing units to facility.
- Verify simulator/servicing units to racks/experiments/pallet interfaces.
- Connect simulator/servicing units to racks/experiments/pallet interfaces.

Emplacement of the SM interface simulator and servicing units will require consideration of the location of facility stub-ups of fluids and power and their locations releveant to the test article. Positioning of these units will require an overhead crane and lifting slings.

Verification of the SM interface simulator and servicing units facility interfaces consists of assuring that connectors mate properly; that power, voltages and regulation are satisfactory; and that servicing fluids have been verified to be proper and contaminant-free. Connections can be made to the facility once these factors have been established.

Similar assurances are made at the test article interface, and connections are then made to the test article. When all fluid connections are satisfactory the test article will be serviced with Freon, water, gases and other fluids required for the up-coming tests.

Sheet 1 of 1

ACTIVITY DATA SHEET

1.0 ACTIVITY IDENTIFICATION

Functional Flow Number: 3.2 Applicable Concepts: ALL

Title: Power Up and Check Out SM Interface Simulator

Principal Elements: Pallet, Racks/Experiment, EM Floor Structure and Aft Bulkhead, Aft Utility Bridge, SM Interface Simulator and Servicing Units

2.0 ACTIVITY DESCRIPTION

After all connections with support equipment have been made, the SM interface simulator will be checked out prior to starting the experiment integration tests. This subtask deals with that activity and includes the following:

- Power up coolant loops and verify flows and controls.
- Perform bus isolation tests prior to power-up of racks/experiments/pallets.
- Conduct pre-power switch list verification of switch and control settings.
- Power up SM interface simulator, excluding computer functions.
- Conduct power distribution checks.
- Verify caution/warning functions.
- Power up SM interface simulator computer functions.
- Conduct computer/instrumentation self-checks.
- Verify computer command/control.
- Verify computer peripheral equipment operation--printers, recorders, plotters, etc.
- Verify compatibility with ground data base (GDB) via GDB umbilical.
- Verify racks/experiments auxiliary equipment performance--CCTV, intercom, etc.
- Power down all electrical/mechanical systems and GSE.

ACTIVITY DATA SHEET

1.0 ACTIVITY IDENTIFICATION

Functional Flow Number: 3.3 Applicable Concepts: ALL

Title: Experiments Integration Readiness Review

Principal Elements: Pallet, Racks/Experiment, EM Floor Structure and Aft Bulkhead, Aft Utility Bridge, SM Interface Simulator and Servicing Units

2.0 ACTIVITY DESCRIPTION

Following the SM interface simulator and supporting GSE checkout, an Experiment Integration Readiness Review is required. The purpose of this review is to obtain formal NASA approval to start the experiment integration tests. All data and documentation developed (data pack) up to this stage of testing that are relevant to experiment integration will be reviewed. Such data will consist of all open items, test anomalies, discrepancies, shortages, etc., which must be reviewed by a board composed of contractor and NASA personnel, including principal investigators (PI's).

BLOCK 4.0 EXPERIMENT INTEGRATION

```
****1****2****3****4****5****6****7****8 WORKING WEEKS

*   TEST TEAM CALL TO STATIONS FOR EXPERIMENT INTEGRATION TESTS
*   RACKS/EXPMT'S-SM INTERFACE SIMULATOR SET SW LIST VERIFICATION
*   POWER UP RACKS/EXPMT'S & SM INTERFACE SIM SET/SUPPORT GSE
************  CONDUCT INDIVIDUAL EXPERIMENTS C/O BY DISCIPLINE
              **************  CONDUCT EXPMT'S INTEGRATED SYSTEMS TESTS
                              ********  CONDUCT EMC/RFI TESTS & ANALYSIS
                                      *   POWER DOWN
                                      **   DATA REVIEW
                                       *   WORK DISCREPANT ITEMS
                                        *    SYSTEM RETEST
                                        *    NASA ACCEPTANCE REVIEW
```


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ACTIVITY DATA SHEET

1.0 ACTIVITY IDENTIFICATION

Functional Flow Number: 4.0 Applicable Concepts: ALL

Title: Experiment Integration

Principal Elements: Pallet, Racks, Experiments, EM Floor Structure, EM Aft Bulkhead, Aft Utility Bridge, SM Interface Simulator and Servicing Units

2.0 ACTIVITY DESCRIPTION

Upon receipt of formal approval to proceed (from NASA), the experiment integration tests (Level III) will begin with test team call to stations. All personnel involved in the integration tests will report to their test station and verify readiness to support testing to the test conductor on the test communications network.

After test team report-in is complete, a switch list verification will be conducted on the test network intercom to verify switch positions and control settings of the test article and all GSE supporting the test.

Satisfactory completion of the switch list verification is followed by power-up of SM interface simulator, servicing units, test article and other required support equipment. Individual and integrated experiments tests will be conducted, including EMC/RFI tests.

Crew training can be augmented by conducting abbreviated mission simulations in parallel with the integrated experiments checkout. This effort should, naturally, involve the flight personnel expected to operate the experiment equipment on the up-coming mission.

Following power-down from the experiment integration tests, a brief data review will be held, discrepancies identified, dispositioned, worked, and re-tested prior to final NASA acceptance review.

ACTIVITY DATA SHEET

1.0 ACTIVITY IDENTIFICATION

Functional Flow Number: 4.1 Applicable Concepts: ALL

Title: Individual Experiment Checkout by Discipline

Principal Elements: Pallet, Racks, Experiments, EM Floor Structure, EM Aft Bulkhead, Aft Utility Bridge, SM Interface Simulator and Servicing Units

2.0 ACTIVITY DESCRIPTION

The experiment integration tests will be initiated by conducting individual experiment checkout by discipline. A typical payload was assumed in the formation of the test timelines, and the disciplines considered were:

- Navigation
- Earth Observation
- Environmental Effects
- Components and Systems
- Microbiology
- Physics and Chemistry

If the configuration of the experiments are such that it is feasible to perform all the Navigation Experiments checkout, for instance, before performing Environmental Effects, then testing will be performed in this manner. The order of testing by discipline will be planned to maximize parallel activity. Several experiments may comprise a discipline with tests of the various experiments occurring individually. Testing in this way tends to increase efficiency since a single principal investigator (PI) or designee, familiar with all experiments in a given discipline, could act as an observer/consultant.

The individual experiment checkout will be concluded when the test conductor coordinating the tests has verified that all procedural requirements have been met.

ACTIVITY DATA SHEET

1.0 ACTIVITY IDENTIFICATION

Functional Flow Number: 4.2 Applicable Concepts: ALL

Title: Experiments Integrated Systems, EMC/RFI Tests

Principal Elements: Pallet, Racks, Experiments, EM Floor Structure, EM Aft Bulkhead, Aft Utility Bridge, SM Interface Simulator and Servicing Units

2.0 ACTIVITY DESCRIPTION

Following completion of the individual experiment checkout by discipline, integrated experiment checkout will be started. During this stage of testing, experiments that would normally function together during the mission will be evaluated for interaction and interferences between systems. Electromagnetic compatibility (EMC) and radio frequency interference (RFI) testing will be systematically performed during experiment checkout. Simulated missions, using an abbreviated mission flight plan, is an effective method for augmenting crew training without detracting from the experiment integration tests. Flight crew personnel will be utilized for those tests where checkout can be feasibly combined with training.

Experiment integration tests will verify the deployment/operation of booms, antennas, solar arrays, etc., including those that may require special one-g support structure for their deployment. Once these systems have been verified, however, subsequent operations at other sites will not be attempted unless there is evidence that their functional behavior has changed.

The experiment integration tests will end when the test conductor coordinating the tests has verified that all procedural requirements have been met.

ACTIVITY DATA SHEET

1.0 ACTIVITY IDENTIFICATION

Functional Flow Number: 4.3 Applicable Concepts: ALL

Title: Data Review, Discrepancy Rework and System Re-Test

Principal Elements: Pallet, Racks, Experiments, EM Floor Structure, EM Aft Bulkhead, Aft Utility Bridge, SM Interface Simulator and Servicing Units

2.0 ACTIVITY DESCRIPTION

All data gathered during the individual and experiment integration tests will be reviewed by a joint board of NASA and contractor personnel. The purpose of this review is to determine the extent to which specifications and procedural requirements have been met by comparing them against records of system performance. Discrepancies will be evaluated, fixes will be outlined and re-test requirements established. Satisfactory completion of re-test requirements is necessary prior to NASA acceptance review of the experiment integration.

ACTIVITY DATA SHEET

1.0 ACTIVITY IDENTIFICATION

Functional Flow Number: 4.4 Applicable Concepts: ALL

Title: Acceptance Review

Principal Elements: Pallet, Racks, Experiments, EM Floor Structure, EM Aft Bulkhead, AFT Utility Bridge, SM Interface Simulator and Servicing Units

2.0 ACTIVITY DESCRIPTION

A formal acceptance review follows the completion of the experiment integration (Level III) tests. All documentation developed to this stage of testing will be the subject of this review. NASA, assisted by contractor personnel, will determine the extent to which Level III testing has been satisfied. Formal approval to begin Spacelab integration tests (Level II) is the output goal of this review. The importance of the review is emphasized by the fact that for Concepts II, III and IV, approval constitutes authorization to ship the racks/experiments-pallet configuration to the launch site.

BLOCK 5.0 GSE DISCONNECT

**********1**********2 WORKING DAYS

** DISCONNECT SM SIMULATOR SET FROM RACKS/EXPERIMENTS
**** DISCONNECT REMAINING GSE, SERVICING UNITS, ETC
******** POST TEST CLEAN UP & CLEAR EXPERIMENT C/O AREA

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ACTIVITY DATA SHEET

1.0 ACTIVITY IDENTIFICATION

Functional Flow Number: 5.0 Applicable Concepts: ALL

Title: GSE Disconnect

Principal Elements: Pallet, Racks, Experiments, EM Floor Structure, EM Aft Bulkhead, AFT Utility Bridge, SM Interface Simulator and Servicing Units

2.0 ACTIVITY DESCRIPTION

In parallel with the acceptance review, the support module interface simulator and other supporting equipment will be disconnected. Post-test cleanup and clearing the experiment checkout work area is the major activity of this task. Removal of personnel access stands, special lighting, and small laboratory-type test equipment is part of this effort.

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BLOCK 6.0 RACKS/PALLET SHIPMENT

```
*******1*******2*******3*******4*******5*******6*******7*******8 WORKING DAYS

**  MOVE RACKS/PALLET TO SHIPMENT AREA
  ****  RETOUCH THERMAL PAINT ON EXTERNAL SURFACES
     ***  CONNECT LIFTING DEVICES TO RACK/PALLET
        ****  LOAD RACKS/PALLET IN SHIPPING CONTAINER, SECURE & REMOVE LIFTING DEVICES
           **  INSTALL SHIP CNTR PORTABLE  PRESSURIZATION UNIT & ACTIVATE
             **  MOVE SHIP CNTR TO AIR CARRIER LOADING SITE
               **  LOAD SHIP CNTR ON AIR CARRIER
                 ***************  RACKS/PALLET ENROUTE TO LAUNCH SITE
                                *  RACKS/PALLET ARRIVAL AT LAUNCH SITE
                                ****  OFFLOAD SHIP CNTR & XPORT TO SL INTEGRATION AREA
                                    ****  REMOVE SHIP CNTR COVER & PRESS UNIT
                                        ****  CONNECT LIFTING DEVICES & REMOVE
                                              RACKS/PALLET
                                           **  MOVE R/P INTO MATING STAND & REMOVE
                                              LIFTING DEVICES
                                            ***  INSTALL PROTECTIVE COVERS/PADS
                                            ******  REMOVE INSP PANELS/COVERS &
                                                    CONDUCT R/I
```


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ACTIVITY DATA SHEET

1.0 ACTIVITY IDENTIFICATION

Functional Flow Number: 6.0 Applicable Concepts: ALL

Title: Racks/Pallet Shipment

Principal Elements: Pallet, Racks/Experiment, EM Floor Structure, EM Aft Bulkhead and Aft Utility Bridge

2.0 ACTIVITY DESCRIPTION

The racks/experiments/pallet shipment follows disconnect of the SM interface simulator and other GSE for certain concepts. The activity comprising this task is as follows.

- Racks/experiments/pallet shipment preparations
- Off-load and conduct receiving/inspection

The shipment approach to be utilized assumes a piggyback transport of the racks/experiments/pallet loaded in an aerodynamic canister aboard a Boeing 747 aircraft. It is further assumed that the structure required to load the canister atop the 747 is supplied as GFE, and this structure is always carried in a disassembled condition aboard the aircraft. In addition, the mobile crane utilized as the prime mover in the loading operation is similarly presumed to be supplied as GFE.

ACTIVITY DATA SHEET

1.0 ACTIVITY IDENTIFICATION

Functional Flow Number: 6.1 Applicable Concepts: ALL

Title: Racks/Experiments/Pallet Shipment Preparations

Principal Elements: Pallet, Racks/Experiment, EM Floor Structure, EM Aft Bulkhead and Aft Utility Bridge

2.0 ACTIVITY DESCRIPTION

This subtask covers the shipment preparations of the racks/experiments/pallet. It starts with the movement of the racks/experiments/pallet to the shipment preparation area where the unit is cleaned and vacuumed to remove dirt and debris accumulated during test. Closeout inspection and access covers/panels are installed and all external surfaces of the racks/experiments/pallet, exposed to solar radiation, requiring application of thermal protective coatings, will be painted. Lifing devices (slings/hoists) are then connected in preparation for loading the racks/experiments/pallet into the shipping canister. Verification of proof-load certification of all lifting devices is necessary prior to proceeding with lifting operations.

After the racks/experiments/pallet have been loaded in the shipping container, secured, and lifting devices removed, the canister portable pressurization unit and aerodynamic fairings are installed. The pressurization unit is activated and the canister is placed on its transporter for move to the air carrier loading site. Assembly of the loading structure for the canister (normally available at the loading site) will have been completed, and a prime mover (mobile crane) will be standing by to load the canister.

The loading operation will consist of placing and securing the canister, piggyback, atop the 747 aircraft; the loading structure will be disassembled and placed aboard the aircraft for subsequent unloading operations at the launch site. The enroute time for the transfer is arbitrarily chosen as two days to account for adverse weather and other factors affecting air transport.

ACTIVITY DATA SHEET

1.0 ACTIVITY IDENTIFICATION

Functional Flow Number: 6.2 Applicable Concepts: ALL

Title: Racks/Experiments/Pallet Off-Load and Conduct Receiving/ Inspection (R/I)

Principal Elements: Pallet, Racks/Experiment, EM Floor Structure, EM Aft Bulkhead and Aft Utility Bridge

2.0 ACTIVITY DESCRIPTION

Upon arrival at the launch site, the shipping canister will be off-loaded from the Boeing 747 aircraft and transported to the Spacelab integration area. The shipping container cover and pressurization unit are removed and lifting devices attached to the racks/experiments/pallet. The unit is removed from the canister and installed in a work stand. Lifting devices are removed and equipment/experiments protective covers/pads are installed.

A procedural receiving/inspection (R/I) will be performed after all inspection panels/covers have been removed. A status review of all documentation will be performed to verify the validity of the "data pack" accompanying the racks/experiments/pallet.

New test and inspection records (TAIR books) will be prepared at the launch site as an expediency for consolidation of documentation. A universal format for documentation between the various NASA centers would tend to obviate the necessity for initiating new accounting systems at each site.

BLOCK 7.0 MATE RACKS/PALLET-EM/SM SHELLS

```
*******1*******2*******3********4 WORKING DAYS

****  MOVE EM/SM SHELLS TO SL INTEGRATION AREA
    **  VERIFY MATING SURFACES-EM AFT BLKHD TO EM SHELLS OK TO MATE
      ******  INSPECT/VERIFY ELEC/MECH CONNECTIONS FOR MATE READINESS
            ****  INSTALL ALIGNMENT SET(GSE)
              **  ALIGN EM AFT BLKHD & SHELL INTERFACES
                ***  MATE RACKS/PALLET/AFT BLKHD TO EM/SM SHELLS & SECURE
                   *  VERIFY ELEC BONDING (GROUND) AT SM/EM/P I/F'S
                    ****  CONNECT ELEC/MECH INTERFACES
                      *  INSTALL COND AIR SUPPLY ADP'T & DUCT SET TO SL
                       *  CONNECT COND AIR SUPPLY FROM GND COOLING CART
                       *  INSTALL GSE INTERIOR LIGHTING SET
```


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Sheet 1 of

ACTIVITY DATA SHEET

1.0 ACTIVITY IDENTIFICATION

Functional Flow Number: 7.0 Applicable Concepts: ALL

Title: Mate Racks/Experiments/Pallet-EM/SM Shells

Principal Elements: Racks/Pallet-EM/SM Shells

2.0 ACTIVITY DESCRIPTION

This task is directed toward the assembly of the Spacelab elements into the final flight configuration in order to accomplish the Level II Spacelab integration tests.

The major functional operations to be considered are as follows.

- Movement of Spacelab elements to the Spacelab integration area for assembly.
- Preparations for mate of racks/pallet with EM/SM shells.
- Mate of racks/pallet-EM/SM shells and verifying electrical bond across I/F.
- Connect and verify electrical/mechanical connectors.
- Install GSE.

The EM/SM shells will already have been refurbished from the previous flight at this point in the Spacelab flow (except all fluid systems are in a dry, unserviced condition).

A means must be provided to verify the structural attach points at the Spacelab/Orbiter interface. Consideration of this factor in the design of the Spacelab element mating workstand would afford the most convenient way of accomplishing this verification.

BLOCK 8.0 SPACELAB INTEGRATION

```
***1***2***3***4***5***6***7***8***9**10**11**12   WORKING DAYS

****  CONNECT GSE(SERV UNITS,ORBITER I/F SIM & OTHER SUPPORT GSE)
    **  SERVICE & VERIFY COOLANT FLOW THROUGH GSE, FLD LINES,& COLDPLATES
      *  PERFORM BUS ISOLATION TESTS
       *  CONDUCT PRE-PWR SW LIST CK TO VERIFY SW & CONTROL SETTINGS
        *  PWR UP ELECT & FLUID SYSTEMS
        *  CONDUCT PWR DISTRIBUTION CHECKS
         *  VERIFY CAUTION & WARNING SYS OPERATION -SENSORS & DISPLAYS
         *  POWER UP SUPPORT MODULE IMS
         *  CONDUCT COMPUTER SELF CHECKS
          **  VERIFY SM IMS COMMAND/CONTROL
            *  CHECKOUT EM-IMS PERIPH EQUIP - PRINTERS, RECORDERS, ETC
            *  C/O AUX EQUIP- CTTV, I/C, LIGHTING, ETC.
            *  CHECK SIG DISTR VIA SM-ORBITER UMBILICAL
             *  VERIFY GND DATA BASE COMPATABILITY VIA THE GDB UMB
             ****  CONDUCT FUNCT C/O OF SUPPORT SYS/EXPMT EQUIP I/F'S
                 *  PWR DWN SL & SUPPORT EQUIP
                 *****  DATA REVIEW
                      *****  DISCONNECT GSE
                      *****  LOAD NON-HAZARDOUS SUPPLIES & CREW EQUIP
                         **  CLOSEOUT SL PANELS, HATCHES & ACCESS PANELS
                          ***  RETOUCH SL EXTERIOR WITH THERMAL PAINT
                             ***  CONDUCT EMISSIVITY TESTS
                               **  PREPS FOR SL PRESS DECAY LK CHECK
                                 ****  CONDUCT SL LK CK(24HR PRESS DECAY-16HRS ON 2&3RD
                                       SHIFT
                                     *  DEPRESSURIZE SL & REMOVE GSE
                                      ****  CONDUCT WEIGHT & BALANCE TEST
```


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ACTIVITY DATA SHEET

1.0 ACTIVITY IDENTIFICATION

Functional Flow Number: 8.0 Applicable Concepts: ALL

Title: Spacelab Integration

Principal Elements: Racks/Pallet/Experiments/EM and SM

2.0 ACTIVITY DESCRIPTION

Spacelab integration (or Level II testing) is the major concern of this task. Following completion of the assembly of the Spacelab elements into the final flight configuration, the Spacelab integration tests will be performed in accordance with the following subtask sequence.

- GSE installation and checkout
- Pre-power checks and Spacelab functional checkout
- Data review
- Disconnect GSE and load non-hazardous supplies and crew equipment
- Apply thermal paint, conduct emissivity tests, and Spacelab leak checks
- Conduct Spacelab weight and balance

Depending upon the selected concept, the Spacelab will be prepared either for shipment to the launch site or movement from the MSOB to the OPF upon completion of the Level II tests.

ACTIVITY DATA SHEET

1.0 ACTIVITY IDENTIFICATION

Functional Flow Number: 8.1 Applicable Concepts: ALL

Title: GSE Installation and Checkout

Principal Elements: Racks/Pallet/Experiments/EM and SM

2.0 ACTIVITY DESCRIPTION

This subtask is directed toward the installation and checkout of the fluid servicing units, Orbiter interface simulator and other support equipment.

Servicing of the coolant loops with Freon and water, and gas systems to pressures $\leq$ 25-percent design burst pressure, are the initial steps of this subtask. Coolant and conditioned air flow rates and pressures will be monitored to assure capability to maintain Spacelab equipment temperatures in tolerance.

The Orbiter interface simulator will be checked to verify that its inputs to the Spacelab are representative of the actual Orbiter. The specific items to be evaluated are:

- Fuel cell/power distribution simulation
- Orbital signal simulation
- Orbiter payload specialist station (PSS) equipment
- Umblical interfaces
- Computer and peripheral equipment
- Recording/timing unit
- Operator console

Verification of the functional performance of all GSE to be utilized during test is necessary prior to start of actual Spacelab integration.

ACTIVITY DATA SHEET

1.0 ACTIVITY IDENTIFICATION

Functional Flow Number: 8.2 Applicable Concepts: ALL

Title: Pre-Power Checks and Spacelab Functional Checkout

Principal Elements: Racks/Pallet/Experiments/EM and SM

2.0 ACTIVITY DESCRIPTION

The pre-power checks and Spacelab (SL) functional checkout begin after the GSE has been certified to be ready to support testing.

The effort of this subtask consists of the following:

1. Perform bus isolation tests to verify that all loads are removed from SL bus to ascertain the effect of systematic loading during test, i.e., current versus load tests.

2. Conduct a pre-power switch list to ensure that there are no spurious or unknown loads applied to the SL bus at the start of testing and to verify control/switch positions are proper upon application of SL power.

3. Upon completion of bus isolation and switch list verification, SL power-up of electrical and fluid systems will occur. Bus voltages/current and coolant flow will be carefully monitored during power-up.

4. Power distribution checks will be conducted to verify continuity and functional operation of each circuit, and that all talk-backs (indicators) are consistent with the performed operation.

5. The SL caution/warning (C/W) system operations will be verified to be functional prior to start of system testing. Push-to-test C/W circuits, resets and talk-backs will be checked. All sensors and displays must be working properly before system testing can begin.

ACTIVITY DATA SHEET

-2.0 ACTIVITY DESCRIPTION (CONT)

Flow Number: 8.2

6. Computer systems will be the first to be activated. Since the computer is fundamental to the command and control of other SL systems, it is necessary to verify computer performance through a computer self-check routine. When it is known that computer operation is proper, command and control tests will occur to verify performance of the information management system (IMS). These tests will be conducted by a special computer program routine to verify command and response functions prior to subjecting systems to actual control by the IMS. These latter tests can be considered as procedural verification checks. Computer peripheral equipment, line printers, recorders, etc., are to be evaluated as an adjunct to the computer tests.

7. SL auxiliary equipment such as closed circuit TV (CCTV), intercom and SL interior lighting are factors involving crew habitability which will require flight crew participation for proper evaluation.

8. SL signal distribution and ground data base (GDB) compatibility via the Spacelab/Orbiter and GDB access umbilicals are part of the SL integration effort.

9. The final activity of this subtask is the SL functional checkout of support systems and experiment equipment interfaces. Control and command of SL functions are to be accomplished via the IMS system as the primary mode. Flight crew emergency backup modes are to be evaluated if feasible. Experiment equipment interfaces only are to be evaluated during SL integration, i.e., experiment operations and functions were assessed during the experiment integration tests and will not be repeated. Following completion of SL functional tests, the SL and GSE are powered-down for a review of accumulated data.

ACTIVITY DATA SHEET

1.0 ACTIVITY IDENTIFICATION

Functional Flow Number: 8.3 Applicable Concepts: ALL

Title: Data Review

Principal Elements: Racks/Pallet/Experiments/EM and SM

2.0 ACTIVITY DESCRIPTION

A data review of Spacelab integration test data will be accomplished with participation by NASA and contractor personnel. All recorded data from tapes, charts, annotated procedures, etc., will be examined prior to approval for test tear-down. A formal review of one day (as shown in the test flows) assumes that some reduction and tabulation of data have been occurring throughout the progress of the Spacelab integration tests.

ACTIVITY DATA SHEET

1.0 ACTIVITY IDENTIFICATION

Functional Flow Number: 8.4 Applicable Concepts: ALL

Title: Disconnect GSE and Load Non-Hazardous Supplies and Crew Equipment

Principal Elements: Racks/Pallet/Experiments/EM and SM

2.0 ACTIVITY DESCRIPTION

Following approval of Spacelab integration test data results, GSE will be disconnected and non-hazardous supplies and crew equipment shall be loaded. Examples of non-hazardous supplies and crew equipment might be low-pressure gases and crew peronal equipment. Radioactive sources, pyrotechnic devices and high-pressure gases are examples of hazardous items that must be loaded at the launch pad.

After loading is completed, panels, hatches and access doors are installed and the Spacelab is closed out. If it is necessary to perform a crew compartment fit and functional (C^2F^2), it will be performed during this subtask.

ACTIVITY DATA SHEET

1.0 ACTIVITY IDENTIFICATION

Functional Flow Number: 8.5 Applicable Concepts: ALL

Title: Emissivity Tests and Spacelab Leak Check

Principal Elements: Racks/Pallet/Experiments/EM and SM

2.0 ACTIVITY DESCRIPTION

Following closeout of the Spacelab (SL) the surfaces exposed to solar radiation in space may require application or touchup with thermal paint. Emissivity tests are then conducted to verify specification requirements of the ratio of solar absorption to emissivity (α/ε).

In parallel with the emissivity tests, preparations for a SL pressure decay leak check will occur. This latter activity includes connecting the SL to a gaseous fluid distribution system for pressurization with an inert gas such as nitrogen (N_2).

The SL hatch will need to be closed out with a GSE hatch cover and seal capable of withstand a delta-P of TBD psi.

The SL will be pressurized and interior pressure and temperature monitored for a 24-hour period to observe any variation in interior pressure which, when corrected for temperature effects, provides an indication of SL leak rate.

After satisfactory completion of leak rate checks, the SL will be depressurized and the pressurization test setup will be disconnected.

BLOCK 9.0 SPACELAB SHIPMENT TO LAUNCH SITE

```
*******1*******2*******3*******4********5 WORKING DAYS

*  VERIFY LIFTING DEVICES HAVE CURRENT PROOF LOAD
***  CONNECT LIFTING DEVICES
   ***  LOAD SL INTO  SHIPPING CONTAINER & SECURE
      **  CONNECT SHIP CNTR SLING/HOIST & LOAD SL/CNTR ON XPORTER
        **  INSTALL SL PORTABLE PRESS UNIT & ACTIVATE
          **  MOVE SL TO AIR CARRIER LOADING AREA
            *  LOAD SL ON AIR CARRIER & SHIP
             ***************  SPACELAB ENROUTE TO LAUNCH SITE
                           *  SL ARRIVAL AT LS
```


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ACTIVITY DATA SHEET

1.0 ACTIVITY IDENTIFICATION

Functional Flow Number: 9.0 Applicable Concepts: I and V

Title: Spacelab Shipment to Launch Site

Principal Elements: Spacelab (SL)

2.0 ACTIVITY DESCRIPTION

This activity includes the preparations of the SL for shipment to the launch site (LS), the actual air shipment, and concludes with the arrival of the SL.

Prior to the initiation of this block, the following conditions have been successfully completed.

1. All major hardware elemtns [support module (SM), experiment module (EM) and pallet (P)] have been refurbished, reconfigured, and checked out.

2. Experiments, racks and associated equipment have been installed, aligned and functionally checked out.

3. Experiment integration (III) testing and checkout are completed.

4. Spacelab integration (II) has been completed.

All of the checks and tests that can be completed with an Orbiter inferface simulator have been completed and reviewed, with results approved. The successful completion of the above four steps results in an integrated SL ready for shipment to the launch site where, following a brief receiving inspection, the SL will undergo Orbiter cargo integration (I) to establish the readiness of the payload for the mission. The six principal activities associated with preparations for, and shipment of, the SL are:

1. Verification of the current proof-load status of the GSE lifting devices that will be used for SL loading. This operation is necessary to ensure that any overhead cranes, slings, or hoists that lift the Spacelab have been accurately rated and are fully capable of handling the SL.

ACTIVITY DATA SHEET

2.0 ACTIVITY DESCRIPTION (CONT)

Flow Number: 9.0

2. Connect the lifting devices to the SL. This second operation involves the connecting of the sling/hoist to the SL hydraset and traveling overhead crane.

3. Once this connection has been completed, the SL will be loaded into the canister and secured to avoid damage during movement/shipment.

4. The canister will then be connected to the sling/hoist and loaded on the transporter. The canister must also be tied down to avoid damage.

5. After the canister has been loaded on the transporter and closed out, the portable pressurization until will be installed and activated to maintain a positive pressure on the SM and EM. Throughout all of the installation, testing, checkout and integration periods the SL and its experiments have been kept in a cleanroom environment (100,000 class). Use of the pressurization unit will ensure that the SL remains free of particulate contamination during shipment.

6. The SL is now ready to be moved by tractor or truck to the airstrip where it will be loaded aboard the Boeing 747. The canister will be instrumented (temperatures, pressures, vibration, shock, etc.), and these measurements recorded on a trip log at the end of the flight. Analysis of the data recorded by these devices will be made as part of the SL receiving/inspection.

BLOCK 10.0 SPACELAB OFFLOAD

```
*******1*******2*******3*******4 WORKING DAYS

*  SPACELAB ARRIVAL AT LS
****  OFFLOAD SL & XPORT TO MSOB
    ****  REMOVE SHIP CNTR COVER & PRESS UNIT
        ****  CONNECT LIFTING DEVICES & REMOVE SL
            ***  MOVE SL INTO WORK DOLLY & REMOVE LIFTING DEVICES
               ***  REMOVE SM(GSE) HATCH/SEAL, INSTALL PROTECTIVE CVR'S/PADS, COND
                    AIR/GSE LIGHTS
               ****  REMOVE INSP PANELS/COVERS & CONDUCT R/I
                  ***  REINSTALL PANELS/COVERS
```


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ACTIVITY DATA SHEET

1.0 ACTIVITY IDENTIFICATION

Functional Flow Number: 10.0 Applicable Concepts: I and V

Title: Spacelab Off-Load

Principal Elements: Spacelab (SL)

2.0 ACTIVITY DESCRIPTION

The SL will be shipped to the launch site (LS) by air. The canister containing the SL will be extracted from the Boeing 747 and placed (by GSE located at the LS) on the transporter for subsequent shipment to the LS. A tractor or truck will move the transporter from landing site to the MSOB. Once in the MSOB, the portable pressurization unit will be disconnected and removed and the SL lifted out of the shipping container. The lifting of the SL will be a carefully supervised operation. It is of utmost importance that the slings and hoists are securely connected to the SL. Once extracted from the canister, the SL will be moved into its work dolly and secured, and the lifting devices removed. Access to the SL will be reestablished by removal of the SM (GSE) hatch/seal. Crewmen will install the protective pads and covers to ensure that equipment will not be disturbed or damaged by workmen operating in the interior of the SL.

Also, to facilitate the efforts of the T&O technicians and the crew, conditioned air and GSE portable lighting will be installed in the interior of the SL. After the SL has been prepared for work crews, the inspection panels and covers will be removed and a receiving inspection (R/I) will be performed. This R/I will be a review of the monitoring devices that establish the environment that the SL went through during its shipment to the LS.

Once the R/I has been completed and the results found to be satisfactory, the inspection panels/covers will be reinstalled and the SL is now ready for its final checks leading to the reference mission.

BLOCK 11.0 ORBITER CARGO INTEGRATION

```
*******1*******2*******3*******4*******5*******6 WORKING DAYS

**************************  8 HOUR WORK DAY
***  CONNECT SL LIFTING DEVICE & LOAD SL IN SHIP CNTR/DISCONNECT SL LIFT DEVICES
   **  CONNECT SHIP CNTR LIFT SLING/HOIST & LOAD SL/CNTR ON XPORTER
     **  MOVE SL TO ORBITER PROCESSING FACILITY (OPF)
       ****  OFFLOAD SL IN OPF SL/ORBITER LOAD PREP AREA
           **  REMOVE SLING/HOIST
             **  REM SL FR SHIP CNTR, GSE HATCH/SEAL-INSTL H/SEAL PROT CVR-CNCT A/C & GSE
                 LGTS
               **  CK SL/ORBITER I/F CONNECTIONS- ELEC/MECH
                ****  SERVICE SL WITH NON-HAZ FLUIDS & LOW PRESS GAS
                    ****  INSTALL FLT BATTERIES & CHARGERS
             **********  INSTALL SL RELATED EQUIP IN ORB CREW COMPARTMENT
                       *  VERIFY ORB READINESS TO ACCEPT SL
                       *  REM HATCH SEAL PROT CVR -A/C & GSE LGT'S
                        **  CONNECT LIFTING SLING/HOIST
                          **********  16 HOUR WORK DAY
                          **  INSTALL SL IN ORBITER & SECURE
                           *  REM LIFTING SLING/HOIST
                            *  ORB/SL I/F VERIF(PLUGS OUT CONT-CNCT CABLES/FLD
                               LINES/UMB'S & TUNNEL)
                             ******  CONDUCT ORB INTEG TEST (OIT) WITH SL
                                  *  EMC/RFI TEST W/SL/ORB SYS OPERATING
                                   *  INSTALL/CNCT ORD NOT ACCESSIBLE AT PAD
                                   **  CONDUCT ABBREV SL LK CK OF TUNNEL & HATCH & FINAL
                                       SL CLOSEOUT
                                   **  SL DATA REVIEW & SL FINAL FLT APPROVAL
```


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ACTIVITY DATA SHEET

1.0 ACTIVITY IDENTIFICATION

Functional Flow Number: 11.0 Applicable Concepts: ALL

Title: Orbiter Cargo Integration

Principal Elements: Spacelab/Orbiter/Tunnel

2.0 ACTIVITY DESCRIPTION

Orbiter cargo integration (Level I tests) relates to the activity required to move, install, check out and final close out of the Spacelab (SL) in the Orbiter cargo bay; specifically, the subtask items are as follows.

- Preparations and movement of the SL to the Orbiter Processing Facility (OPF).
- Preparations and installation of Spacelab in Orbiter.
- Orbiter integrated test (OIT), electromagnetic compatibility (EMC) and radio frequency interference (RFI) tests.
- SL final closeout.
- Data review and final flight approval.

A common timeline for the Orbiter/Spacelab processing flows occurs approximately three days after the start of Orbiter cargo integration. From this stage in the SL flows, through launch, mission and Orbiter landing, the Orbiter processing flow is the driving influence on SL timelines. This time span represents the only interval in the SL processing flows in which a two-shift 8-hour/shift work period is considered; all other times are based on an 8-hour/shift, single-shift/day. The Spacelab/Orbiter cargo integration flow is consistent with the Shuttle Turnaround Allocation Flow (dated April 23, 1974) as shown in Revision 1 of Shuttle System Ground Operations Plan (K-SM-09), dated May 31, 1974.

ACTIVITY DATA SHEET

1.0 ACTIVITY IDENTIFICATION

Functional Flow Number: 11.1 Applicable Concepts: ALL

Title: Preparations and Moving Spacelab (SL) to OPF

Principal Elements: Spacelab/Orbiter/Tunnel

2.0 ACTIVITY DESCRIPTION

This subtask begins with connecting the lifting devices to the SL, followed by loading operations into the SL shipping canister, and disconnection of lifting devices. Lifting devices are then connected to the canister for loading on transporter. A blanket pressure (GN_2) might be placed inside the canister to preclude entry of contaminated air during the move from the MSOB to the OPF. Some SL/experiment configurations may have unique cooling requirements; so for these configurations, special cooling systems may be necessary as part of the canister design. It is clear that one would not have a canister blanket pressure simultaneously with an air-conditioned canister interior; consequently, the SL/experiment configuration is fundamental to the choice of method. The point of this discussion is to emphasize that the move preparations are dependent upon SL/experiment configuration and therefore cannot be completely defined.

The actual move of the SL to the OPF from the MSOB requires about two hours because of very low transport speeds (< 5 mph) necessary to mitigate road shock.

At the OPF, the SL is removed from the canister, after off-load from the transporter, and placed in a suitable SL/Orbiter load preparation work stand. The GSE hatch cover and seal are removed from the SM hatch, and a hatch surface/seal protective cover is installed. Conditioned air and GSE lighting are installed and access stands set up to facilitate SL preloading operations.

ACTIVITY DATA SHEET

1.0 ACTIVITY IDENTIFICATION

Functional Flow Number: 11.2 Applicable Concepts: ALL

Title: Preparations and Installation of Spacelab (SL)

Principal Elements: Spacelab/Orbiter/Tunnel

2.0 ACTIVITY DESCRIPTION

After the SL has been emplaced in its workstand, and access provisions made, the electrical and mechanical Spacelab/Orbiter interface connections are checked. The SL is next serviced with non-hazardous fluids and low-pressure gases (if required), and flight batteries and chargers are installed.

In parallel with the above activity, the installation of experiment-related equipment in the PSS of the Orbiter will continue.

Upon notification that the Orbiter is ready to accept the SL. the SM hatch seal protective cover, conditioned air and adapter, and GSE lighting will be removed from the SL. The lifting devices are connected and the SL is installed in the Orbiter cargo bay. The attach points of the SL in the Orbiter have been previously verified during SL integration.

After the SL has been secured in the cargo bay, the lifting devices are removed and Spacelab/Orbiter interface verification begins. The electrical interfaces are verified with plugs-out continuity checks; and after thorough examination, all electrical cables, fluid lines and umbilicals will be connected. The forward utility bridge and tunnel will be installed and connected. Satisfactory conclusion of these operations represents the final activity of this subtask. It should be noted that the common timeline of the Spacelab/Orbiter begins upon installation of the SL in the Orbiter cargo bay.

Sheet 1 of 1

ACTIVITY DATA SHEET

1.0 ACTIVITY IDENTIFICATION

Functional Flow Number: 11.3 Applicable Concepts: ALL

Title: Orbiter Integrated Test (OIT), EMC and RFI Tests

Principal Elements: Spacelab/Orbiter/Tunnel

2.0 ACTIVITY DESCRIPTION

The Orbiter Integrated Test (OIT) is a test requirement for Shuttle and is shown in the Shuttle Turnaround Allocation. The OIT shown in the Spacelab (SL) flows is consistent with the Orbiter timeline and reflects the SL role in the test. During the OIT, Orbiter and Spacelab systems are operated in various sequences to determine interferences between systems. Electrical transients and spurious signals often caused by operation of pumps, motors, etc., will be specifically investigated.

In parallel with the OIT, EMC and RFI tests are conducted with Spacelab and Orbiter systems operating. The electromagnetic compatibility and radio frequency interference tests will have to be accomplished in various combinations and sequences of system operation. The documented performance characteristics of equipment may result in changes to the mission flight plan pertinent to rearrangement of experiment operating times and sequences.

Conclusion of this subtask is necessary before installation of ordnance which is the subject of the next subtask.

ACTIVITY DATA SHEET

1.0 ACTIVITY IDENTIFICATION

Functional Flow Number: 11.4 Applicable Concepts: ALL

Title: Spacelab Final Closeout

Principal Elements: Spacelab/Orbiter/Tunnel

2.0 ACTIVITY DESCRIPTION

Ordnance not placed in areas accessible at the pad must be installed at this stage of testing. This ordnance includes explosive bolts, shaped charges, etc., used in normal or emergency situations. Installations of pyrotechnic initiators, as a result of safety considerations, are delayed to the very last practical instant in the flows. Normally, during ordnance installation, personnel not actively engaged in the installation operation are required to clear the area.

An abbreviated Spacelab leak check of tunnel interfaces with Orbiter and Spacelab will be conducted. The method of accomplishing this is to be determined, i.e., pressure decay or utilizing helium mass spectrometer.

Spacelab final closeout will occur after leak checks are completed. All panels and inspection covers are installed and cargo bay readied for closeout.

ACTIVITY DATA SHEET

1.0 ACTIVITY IDENTIFICATION

Functional Flow Number: 11.5 Applicable Concepts: ALL

Title: Data Review and Final Flight Approval

Principal Elements: Spacelab/Orbiter/Tunnel

2.0 ACTIVITY DESCRIPTION

A review of all documentation relevant to Spacelab checkout to this point will be conducted with participation by NASA and contractor personnel. The output of this review board will be a formal approval to proceed with Spacelab missions.

BLOCK 12.0 LAUNCH OPERATIONS

```
***************1***************2***************3 WORKING DAYS

*********************************  16 HOUR WORK DAY
              *  INSTALL INTERIOR WORK STANDS FOR ACCESS IN VERTICAL POSITION
               *  INSTALL INTERIOR PROTECTIVE PADS/NETTING(GSE)
                *  CONDUCT SL FINAL PRE-LAUNCH TESTS(PERF PARALLEL WITH ORBITER LRV TEST)
                 *  FINAL SL DATA REVIEW
                 *  LOAD TIME CRITICAL CONSUMABLES (FILM,TAPE,RADIATION FILM PLATES,ETC)
                 *  LOAD TIME CRITICAL LIFE SPECIMENS(CULTURES,ANIMAL'S,INSECTS & PLANTS)
                  ***  LOAD HAZ MATERIALS (CRYOGENS, HYPERGOLICS, HIGH PRESS GAS &
                       RADIATION SOURCES)
                     *  REMOVE SL INTERIOR PROTECTIVE PADS & NETTING
                      *  REMOVE SL INTERIOR WORK STANDS
                                *  LAUNCH
```


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ACTIVITY DATA SHEET

1.0 ACTIVITY IDENTIFICATION

Functional Flow Number: 12.0 Applicable Concepts: ALL

Title: Launch Operations

Principal Elements: Spacelab/Orbiter/Tunnel

2.0 ACTIVITY DESCRIPTION

Following Spacelab (SL) closeout at the conclusion of the Orbiter cargo integration tests, the SL is in a passive mode for approximately 51 hours of the Shuttle turnaround allocated timeline. During this period the SL is inaccessible as a result of operations being performed on the Shuttle in which the Orbiter cargo bay doors are closed out.

After an elapse of 51 hours, the mobile launcher platform (MLP) is hard down on its mounts at the pad, the payload changeout room (PCR) is extended, and cargo bay doors opened. At this time, SL launch operations can be initiated (T -17 hours). Access provisions for the SL interior must consider the vertical orientation of the SL at the pad. From an operational consideration, it is better to minimize the interior activity of the SL because of the access problem, including the necessity for ingress/egress through the Orbiter crew compartment.

For those SL/experiment configurations which require interior SL access, it must be recognized that all ladders, stands and protective padding must pass through the crew compartment and tunnel. This places a definite constraint on the design of such equipment. The activities that can conceivably be conducted at this time are as follows.

1. SL final prelaunch tests (TBD) that would be performed in parallel with the Orbiter launch readiness verification tests (LRV).

2. Loading of time-critical consumables such as film, recording tapes, radiation exposure film plates, radiation sources, etc.

3. Loading of time-critical life specimens that may represent portions of the experiment configuration--cultures, animals, insects, plants, etc.

ACTIVITY DATA SHEET

2.0 ACTIVITY DESCRIPTION (CONT)

Flow Number: 12.0

Loading of hazardous materials such as cryogens, hypergolics, high-pressure gases, etc., would probably be accomplished through external connections to the Spacelab. The total time required for this task should not exceed eight hours, which is consistent with the Shuttle allocation flow.

BLOCK 14.0 POST FLIGHT OPERATIONS

```
**************1**************2**************3**************4 WORKING DAYS

********************  16 HOUR WORK DAY
*  ORBITER LANDING
****************  ORBITER POST LANDING ACTIVITY(REF)
                ****  REMOVE SPACELAB FROM ORBITER
                ****  REMOVE SL RELATED EQUIP FROM ORB CREW COMP(OPERATION NOT PART OF
                      ORB FLOW)
                    ********  BEGIN 8 HOUR WORK DAY/40 HOUR WORK WEEK
                    ********  SHIP SL RELATED EQUIP TO IC(OR USER)-(TASK NOT A SERIAL
                              CONSTRAINT)
                    **  INSTALL SL HATCH COVER
                      ***  INSTALL SL IN SHIPPING CONTAINER & SECURE
```


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ACTIVITY DATA SHEET

1.0 ACTIVITY IDENTIFICATION

Functional Flow Number: 14.0 Applicable Concepts: ALL

Title: Post-Flight Operations

Principal Elements: Spacelab, Experiments from Orbiter Crew Compartment, Canister

2.0 ACTIVITY DESCRIPTION

Post-flight operations commence with Orbiter landing. After landing, the Orbiter will be towed to the safing area where it will be allowed to cool. Residual propellants will be drained and high-pressure gases vented. The Orbiter is made safe in all areas. The same safing procedures will be made on the Spacelab (SL), and all hazardous propellants (if any) are drained and high-pressure gases vented. SL batteries will also be removed at this time if possible.

The first 20 hours of post-flight operations are governed by the planned Orbiter flows. SL activities will be in parallel with analogous Orbiter operations. Within two hours of landing, mobile cooling carts will be attached and activated. Directly following, the Orbiter will be towed to the Orbiter Processing Facility (OPF). After venting and purging have been completed, (about 16 hours after landing), the payload doors can be opened.

Approximately 4 hours are required to disconnect and remove the SL. During the same time period, the ground crew will remove SL experiment equipment from the Orbiter crew compartment. Equipment mounted or stored in the Orbiter will be removed and prepared to be shipped directly to the user facility. The flight crew egress occurs approximately 2 hours after Orbiter landing, and at the same time any critical experiments and data are off-loaded.

Operations during the first 20 hours after Orbiter landing will be conducted at the 16-hour-per-day Orbiter timeline. Completion of SL removal from the cargo bay will allow a decoupling of SL flows from the main Orbiter ground processing flow. At this time, the SL schedule of 8 hours per day, 5 days/week will be initiated.

Prior to SL removal from the Orbiter cargo bay, the SL tunnel will be disconnected along with umbilicals, fluid lines and electrical cables. SL retention device will be released.

ACTIVITY DATA SHEET

2.0 ACTIVITY DESCRIPTION (CONT)

Flow Number: 14.0

The SM hatch cover will be installed to close out the SL prior to shipment. The next operation will be to install the SL in the canister and secure it. If required, time-critical items can be removed from the SL just prior to the closeout of the SM hatch cover. These items could be films, experiment samples or tapes that must be removed and sent to either the principal investigator (PI) or some agency life the Experiment Ground Data Facility.

The next activity will be the attachment of the lifting slings/hoist to the Spacelab and its installation into the canister that will be utilized as the SL shipping container. After the SL has been installed in the canister, it will be secured to avoid damage during shipment.

BLOCK 15.0 SPACELAB MOVE TO MSOB

```
*******1*******2*******3********4 WORKING DAYS

**  CONNECT CONTAINER LIFTING SLING/HOIST & LOAD SL CONTAINER ON XPORTER
  **  MOVE SL/CONTAINER TO MSOB
   *  SL ARRIVAL AT MSOB
    **  REMOVE SHIPPING CONTAINER COVER
      ****  CONNECT LIFTING SLING/HOIST, HYDRASET & REMOVE SL
          ***  MOVE SL INTO WORK DOLLY & REMOVE LIFTING DEVICES
             ***  INSTALL PROT CVR'S/PADS, HOOKUP A/C & GSE LIGHTS
             ****  REMOVE  INSP PANELS/CVR'S & CONDUCT POST FLT INSPECTION
```


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ACTIVITY DATA SHEET

1.0 ACTIVITY IDENTIFICATION

Functional Flow Number: 15.0 Applicable Concepts: II, III, and IV

Title: Spacelab Move to MSOB

Principal Elements: Spacelab, Canister, Transporter

2.0 ACTIVITY DESCRIPTION

After removal of the Spacelab (SL) from the Orbiter and installation in the canister, the SL/transporter will be moved from the OPF to the MSOB. This movement will commence with the connection of the lifting slings and hoist to the canister. After verification of the connections, the SL/canister will be loaded on the transporter. A tractor will move the transporter from the OPF to the MSOB (approximately 2 hours).

After arrival at the MSOB, the canister will be opened. Lifting slings/hoists (with hydraset will be connected and the SL removed and placed into a work dolly. All of the lifting devices will be disconnected and removed. The SL will now be made ready for a post-mission inspection. Protective covers/pads will be installed to avoid having work crews damage any of the SL components or experiments. To assist the crews while they are working inside the SL, conditioned air lines will be brought through the SM hatch and portable GSE lighting will be installed in the SL interior.

The final task of this activity will be the removal of the SL inspection panels and covers followed by a post-flight inspection of the entire SL and pallet. This inspection is an inspection of the as-flown configuration. It is conducted to gain insight into any immediate problems that might require replacement or refurbishment prior to the next mission. The notes from this post-flight inspection will be used by the crew that conducts the SL refurbishment activities of Blocks 19.0 and 21.0.

BLOCK 16.0 SPACELAB SHIPMENT FROM LAUNCH SITE

```
*******1*******2*******3*******4*******5*******6*******7 WORKING DAYS

**  CONNECT CNTR LIFTING SLING/HOIST & LOAD SL/CNTR ON XPORTER
  **  INSTALL PORTABLE PRESSURIZATION UNIT
    **  MOVE SL/CNTR TO AIR CARRIER LOADING SITE
      *  LOAD SL SHIP CONTAINER ABOARD AIR CARRIER
       ****************  SPACELAB ENROUTE FROM LAUNCH SITE
                      *  SPACELAB ARRIVAL FROM LS
                       ****  OFFLOAD SL & XPORT TO EXPM'T INTEGRATION AREA
                           ****  REMOVE SHIP CNTR CVR/PRESS UNIT
                               ****  CONNECT LIFTING SLING/HOIST, HYDRASET & REMOVE SL
                                   ***  MOVE SL INTO WORK DOLLY & REMOVE SLING/HOIST &
                                        HYDRASET
                                  ***  REMOVE SL GSE HATCH CVR & INSTALL PROT
                                       CVR'S/PADS, CONNECT A/C & GSE LIGHTS
                                  *****  REMOVE INSPECTION CVR'S/PANELS, CONDUCT R/I
                                         & POST FLT INSPECTION
```


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ACTIVITY DATA SHEET

1.0 ACTIVITY IDENTIFICATION

Functional Flow Number: 16.0 Applicable Concepts: I and V

Title: Spacelab Shipment from Launch Site (LS)

Principal Elements: Spacelab, Canister, and Transporter

2.0 ACTIVITY DESCRIPTION

After removal of the Spacelab (SL) from the Orbiter (Block 14.0) and installation in the canister, the following tasks will have to be completed to effect SL shipment from the LS. Slings/hoists will be connected to the SL canister and then the entire assembly (canister and SL) is loaded on the transporter. After loading and securing of the canister and transporter, the portable SL pressurization unit will be installed and activated. This unit will provide a slightly positive pressure within the canister and avoid the collection of dust or contamination in the SL. The SL will be moved to the air strip by tractor. When the canister is ready to be moved to the LS, there are two items that have to be completed.

- Notification of security escort of movement plans and routes.
- Receipt of verification of route clearances and that there are no objections to the move.

At the air strip, the canister will be loaded aboard the Boeing 747 and flown to the integration center/user facility.

Two days serial time have been included in the flows as the time necessary to fly the Spacelab from the LS to the next facility.

After arrival at integration center/user facility, the Spacelab/canister will be off-loaded from the 747 and transported to the experiment integration area. When the canister/transport have been secured, the SM portable pressurization unit will be deactivated and removed and the canister cover will be removed. Lifting slings/hoists will be connected to the SL, all ties disconnected and the SL removed.

The SL will be placed onto a work dolly and all lifting devices disconnected and removed. The SL will now be made ready for post-mission inspection. Protective covers/pads will be installed to avoid having work crews damage

ACTIVITY DATA SHEET

2.0 ACTIVITY DESCRIPTION (CONT)

Flow Number: 16.0

any of the SL components or experiments. To assist the crews while they are working inside the SL, conditioned air lines will be brought through the SM hatch and portable GSE lighting will be installed in the SL interior.

The final task of this activity will be the removal of the SL inspection panels and covers, followed by a post-flight inspection of the entire SL and pallet. This inspection is a visual one of the as-flown configuration. It is conducted to gain insight into any immediate problems that might require replacement or refurbishment prior to the next mission.

BLOCK 17.0 DEMATE SM/EM SHELLS

*******1*******2*******3 WORKING DAYS

```
**  REMOVE A/C, A/C ADAPTER & GSE LIGHTING
 **  DISCONNECT ELEC/MECH CONNECTORS
   **  REMOVE ATTACH BOLTS AT EM AFT BLKHD/EM SHELL
     *  SEPARATE RACK/PALLET-EM/SM SHELLS
      ****  MOVE EM/SM SHELLS TO REFURBISHMENT AREA
```


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ACTIVITY DATA SHEET

1.0 ACTIVITY IDENTIFICATION

Functional Flow Number: 17.0 Applicable Concepts: ALL

Title: Support Module/Experiment Module (SM/EM) Shells

Principal Elements:

2.0 ACTIVITY DESCRIPTION

Subseqeunt to the post-flight inspection of the Spacelab, demate operations of the SM/EM from the pallet and EM aft bulkhead and floor structure are accomplished. The personnel cooling and GSE lighting are removed and all electrical/mechanical interface connections are broken at the racks. The attach bolts/fasteners are removed from the EM aft bulkhead to EM shell and the EM floor structure, aft bulkhead and pallet are slid out of the SM/EM shells on the specially designed workstand. The SM/EM shells are moved to the refurbishment area. The EM floor structure, aft bulkhead and pallet with racks and experiments are sent to their refurbishment location. All protective devices will be placed on Spacelab elements as required. A jury strut or GSE brace will be installed on EM floor structure to support the EM aft bulkheads.

BLOCK 18.0 RACKS/PALLET SHIPMENT

```
*******1*******2*******3*******4*******5*******6*******7*******8 WORKING DAYS

***  MOVE RACKS/PALLET TO SHIPMENT AREA
   ***  CONNECT LIFTING DEVICES
      ****  LOAD RACKS/PALLET IN SHIPPING CONTAINER
          **  INSTALL SHIP CNTR PORTABLE PRESS UNIT & ACTIVATE
            ***  MOVE SHIP CNTR TO AIR CARRIER LOADING SITE
               ***  LOAD SHIP CNTR ON AIR CARRIER
                  ****************  RACKS/PALLET ENROUTE TO REFURBISHMENT CENTER
                                 *  RACKS/PALLET ARRIVAL AT REFURB CENTER
                                  ****  OFFLOAD SHIP CNTR & XPORT TO REFURB CENTER
                                      ****  REMOVE SHIP CNTR COVER & PORT PRESS UNIT
                                          ****  CONNECT LIFTING DEVICES & REM RACKS/PALLET
                                              **  MOVE RACKS/PALLET INTO WORK STAND & REM
                                                  LIFT DEVICES
                                                ***  INSTALL PROTECTIVE CVR'S/PADS
                                                ******  REMOVE INSP PANELS/CVR'S &
                                                        CONDUCT R/I & POST FLT INSPECTION
```


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ACTIVITY DATA SHEET

1.0 ACTIVITY IDENTIFICATION

Functional Flow Number: 18.0 Applicable Concepts: II, III, & IV

Title: Racks/Pallet Shipment

Principal Elements: Racks, Pallet, Shipping Canister

2.0 ACTIVITY DESCRIPTION

In all concepts, the racks/pallet (R/P) are shipped to the facility where they will be repaired and refurbished. This activity commences with the movement of the R/P's to the shipment area where they will be loaded in a shipping container. A portable pressurization unit will be installed on the shipping canister and activated. The pressurization unit will supply a slight positive pressure on the R/P's to avoid contamination during shipping. The shipping container will be taken to the air carrier loading site by transporter. Once loaded on the air carrier, the R/P canister will be flown to the refurbishment center. Two days have been included as the estimate for the serial time to fly the R/P's to the refurbishment center. This allocation may be somewhat on the conservative side, but it was felt that it might be safer to include this margin for unforeseen difficulties or delays.

After the R/P's have arrived at the refurbishment center, the shipping container cover and the protable pressurization unit will both be removed. Lifting devices will be connected to the R/P's and they will be removed from the shipping canister and moved into a work stand.

After the lifting devices have been removed, protective covers and pads will be installed. The final activity of this block will be to conduct a receiving inspection of the racks and pallet. There may be some of this equipment that have inspection panels and covers; these items will be removed and a visual inspection conducted. This will be a preliminary screening to determine that there are no immediate problems requiring attention prior to initiating the pallet/rack refurbishment.

BLOCK 19.0 REFURBISH RACKS/PALLET

```
*******1*******2*******3*******4*******5*******6*******7*******8*******9 WORKING DAYS

********  DRAIN, FLUSH, DRY & CAP COOLANT SYSTEM
         ************************  REMOVE RACKS/EXPERIMENTS
                  ****************  MOVE EXPERIMENTS TO SHIPMENT AREA
                           ****************************************  REFURBISH RACKS
                                    ****************  REM CABLING/FLUID LINES/BKT'S
                                    **********************************  REFURB EM FLOOR, AFT
                                                                        BLKHD & PALLET
                                    ********  VERIFY OPERABILITY OF FLD SYS COMPONENTS
                                             ********  INSP CABLING/CONN/FLD LINES & REPAIR
                                                      ******************  RECONIF EM FLR STRU &
                                                                        FAB ELEC/FLD LINES
                                                      ******************  RECONIF PALLET & FAB
                                                                        ELEC/FLD LINES
                                                      ******************  INSP EM AFT BLKHD
                                                                        MATE SURFACES, REPAIR
                                                                        & ALODINE
                                                      ********  INSP & REPAIR AFT UTILITY BRIDGE
                                                               ********  RE-TOUCH EXP'D SURFACES
                                                                         W/THERMAL PAINT
                                                                  **  VAC & CLEAN
                                                                      RACKS/PALLET STRUCTURE
```


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ACTIVITY DATA SHEET

1.0 ACTIVITY IDENTIFICATION

Functional Flow Number: 19.0 Applicable Concepts: ALL

Title: Refurbish Racks/Pallet

Principal Elements: Experiment and Subsystem Racks, Pallet Sections

2.0 ACTIVITY DESCRIPTION

Within hours of the separation of the EM/SM shells from the racks/experiments and pallet, the refurbishment of all Spacelab hardware elements and experiments will be initiated. Refurbishment of the racks, experiment/racks floor structure, aft bulkhead, pallet and experiments will include the separation, removal and inspection of all these major hardware components. The racks and pallet will be stripped of experiments and auxiliary equipment, down to the basic structure and permanent service fixtures.

The experiments and their associated equipment, removed from the racks and off the pallet, will be returned to the user/principal investigator. Those responsible for these experiments will handle the post-mission examination and possible refurbishment prior to reuse.

Each rack, that will be refurbished, is a riged metal frame similar to a relay rack. Various-sized component elements are installed on each rack. The Spacelab racks, while more complex than a relay rack, are not sufficiently flexible to be reconfigurable between missions. Equipment cooling is accomplished by means of a shelf through which a liquid (or air) flows. Equipment will have to be firmly in contact with the shelf to achieve the desired thermal contact. This means that attachment points (bolt holes) must be cut through the shelf and isolated from the coolant channels. It is not feasible to drill new holes in an old shelf, and constraining all new equipment to an identical baseplate pattern may be prohibitive. Therefore, it is assumed that individual rack layout for each mission is unique for each different rack/experiment assembly.

In addition to the cooling and mechanical support, the rack also contains the electrical wiring (cable harness) and the components of the extended digital data bus (EXDDB). The EXDDB's consist of modems, bus couplers, interface units and signal conditioners. These are active electronic devices that have been described as remote acquisition and control units (RACU's). The RACU's (there will be several in the EM and on the pallet)

ACTIVITY DATA SHEET

2.0 ACTIVITY DESCRIPTION (CONT)

Flow Number: 19.0

share a common cable running to the Spacelab data management computer and are the primary means of collecting data from the instrumentation sensors, and distributing commands to circuit breakers, set-point servos, etc.

Similar to the racks, the pallet is a flat-bed structure on which any external sensor can be loaded. It has the same features and the same limitations just described for the rack. Both rack and pallet may be reusable by stripping down completely and replacing all support equipment and experiments with new components uniquely configured for the next mission.

It cannot be assumed that a subsequent mission will be sufficiently similar so that most of the cabling harnesses, coolant lines and connections and mechanical support brackets will be reused. The reference payloads (Payloads 2 and 3; see Appendix A) support this in that they are quite dissimilar. Therefore, the flows and time schedules of this block consider removal, inspection and refurbishment of almost all support or auxiliary equipment. This includes common payload support equipment, such as tape recorders and XDDB equipment, which will be removed, sent to a lab and bench-checked. Refurbishment will also include the reassembly of the common support elements as well as the construction (but not the assembly) of new cables, support brackets and coldplate plumbing. This new equipment will be installed at the time and location of experiment installation (see Block 2.0). Painting and/or touch-up of the pallet external surfaces with thermal paint will complete this activity.

The five functional steps of this block are:

1. Drain and flush coolant system.
2. Remove experiments, cabling fluid lines, brackets, etc.
3. Examine all cabling, connections and fluid connections for damage; vacuum and clean racks and pallet.
4. Remove EM aft bulkhead and pallet attach bolts. Inspect all mating surfaces and utility bridge for corrosion and repair.
5. Prepare the racks and pallet for installation of experiments and support equipment.

ACTIVITY DATA SHEET

1.0 ACTIVITY IDENTIFICATION

Functional Flow Number: 19.1 Applicable Concepts: ALL

Title: Removal of Experiment and Auxiliary Equipment from Racks and Pallet

Principal Elements: Racks/Pallet

2.0 ACTIVITY DESCRIPTION

To initiate the refurbishment of the racks and pallet, the initial activity in this process will be the removal of these racks from the EM floor structure and, in turn, the experiments from the racks/pallet.

In addition to the experiment equipment that is removed from the rack and pallet, cables, fluidlines and brackets must be removed and/or reconfigured prior to installation of the experiments for the next mission.

Flow paths of removed equipment will be capped and their lines drained-cleaned and checked to verify that there is no fluid contamination. Electronics and communication equipment will be transferred to a lab for maintenance, checkout and repair. Also, the caution/warning devices (lights, annunciators), spacecraft instrumentation and signal conditioners, internal lighting and circuit breakers will be checked verified and replaced as necessary. The equipment, removed and sent to a lab for bench maintenance, will be reinstalled with the new experiment equipment.

This activity will only involve the removal of the experiments and their auxiliary equipment. The tasks associated with their preparations for shipment are described in Block 20.0.

In addition to the experiment equipment there is attitude control equipment (i.e., three-axis gimbal platform, sun sensors, star tracker set, horizon scanner, magnetic field detector) that must be removed, sent to the lab, checked out, and reinstalled when required.

ACTIVITY DATA SHEET

1.0 ACTIVITY IDENTIFICATION

Functional Flow Number: 19.2 Applicable Concepts: ALL

Title: Drain, Flush Coolant System; Reservice and Conduct Flow Performance Checks

Principal Elements: Racks and Pallet

2.0 ACTIVITY DESCRIPTION

The active thermal control assemblies connected to the racks and pallet will be completely serviced and refurbished prior to each mission. This task will involve the following operations.

1. Examination of all fluid lines and connectors for damage and/or wear. If any replacements or repairs are necessary, perform the required action.

2. Drain and flush coolant lines, coldplates and circulating pumps.

3. Verify operability of coolant system components. Check pump speed and inlet and outlet pressures.

4. Examination of connectors (coolant flow lines) at aft utility bridge for pallet-mounted coldplates and interface to SM coolant supply main interface connector.

The refurbishment outlined in this task covers only the active thermal control assemblies/components located on the rack or pallet. It covers the coldplates, pumps, isolation valves, flow controls and the temperature and pressure monitors, plus all associated plumbing lines and connectors. The description of the SM assemblies/components is discussed in Block 21.0.

ACTIVITY DATA SHEET

1.0 ACTIVITY IDENTIFICATION

Functional Flow Number: 19.3 Applicable Concepts: ALL

Title: Cabling/Connector Examination and Repair

Principal Elements: Racks and Pallet

2.0 ACTIVITY DESCRIPTION

After completion of the maintenance and refurbishment of the rack/pallet active thermal control assemblies, it will be necessary to reconnect the lines, fill the system, activate it, and again check all fluid connections for possible leakage at either of the major connect points. It will also be necessary to check the electrical power distribution system throughout the EM rack and to the pallet. This will include a validation of all controls and displays located in the racks.

The electrical power cabling to all racks and subsystem equipment will be checked and replaced where required.

ACTIVITY DATA SHEET

1.0 ACTIVITY IDENTIFICATION

Functional Flow Number: 19.4 Applicable Concepts: ALL

Title: Remove Attach Bolts, Separate EM Aft Bulkhead from Pallet and Cap Fluid Lines

Principal Elements: Racks and Pallet

2.0 ACTIVITY DESCRIPTION

Remove EM aft bulkhead/pallet attach bolts at I/F and separate the dollies supporting the EM aft bulkhead/pallet. Use dolly screw jacks to maintain the interface alignment. Separate the EM aft bulkhead and pallet I/F by moving the dollies apart. Cap/bag all electrical connectors and fluid lines at the aft utility bridge interface. The final step of this activity will be the cleaning of the racks, EM floor structure, aft bulkhead and an inspection of the EM and pallet mating surfaces. This will involve:

- Examining mating surfaces and attach bolts for corrosion/ stress cracks.
- Cleaning and polishing any surface deterioration or corrosion.
- Alodining both mating surfaces.
- Vacuuming and cleaning the interior surface and the exterior of the EM aft bulkhead and pallet.

BLOCK 20.0 EXPERIMENT SHIPMENT

```
*******1*******2*******3*******4*******5*******6*******7 WORKING DAYS

********************  PREP FOR, SHIP & TRAVEL OF FIRST SET OF THREE EXPERIMENTS(TYPICAL)
****  SEAL E/I OR PART IN WEATHERPROOF BAG W/DESSICANT
    ***  INSTALL BAGGED E/I IN SHIP CNTR (SHIP CNTR AVAIL AT SITE)
       ***  PRESSURIZE SHIP CTNR  W/INERT GAS(GN2)
         ***  PREPARE SHIP INSTRUCTIONS/DOCUMENTATION
          **  MOVE EXPM'T TO SHIPPING DOCK
            ********  ENROUTE TRAVEL (3 EXPERIMENTS)
        ********************  SECOND SET OF EXPERIMENTS
                ********************  THIRD SET  OF EXPERIMENTS
                        ********************  FOURTH SET OF EXPERIMENTS
```


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ACTIVITY DATA SHEET

1.0 ACTIVITY IDENTIFICATION

Functional Flow Number: 20.0 Applicable Concepts: ALL

Title: Experiment Shipment

Principal Elements: Experiments and Experiment Racks

2.0 ACTIVITY DESCRIPTION

This activity covers the shipment of the experiment equipment and racks after removal from the Spacelab at the conclusion of a mission. This shipment of experiments and auxiliary equipment will be to the user's site in some concepts (I, II and III), and to the principal investigator's (PI) location in others (Concepts IV and V). The time estimates utilized in the test and operations flows were for shipment from an integration center (IC) to a user location and are considered typical of the serial time that this task might require. It is quite similar to Block 1.0 (initial experiment shipment from user to IC), with the noteable exceptions of:

	TIME (DAYS)
1. Shipping containers fabricated in Block 1.0 do not have to be remade.	0.5
2. Receiving inspection is not necessary after the mission as it was accomplished prior to installation of experiments in the Spacelab.	1.0
	1.5

Therefore, Block 20.0 is 1.5 days shorter than Block 1.0.

The activity involves sealing of each part in weather-proof bags or similar protection:

- Installing the bagged component/experiment in a shipping container.
- Pressurization of the container with an inert gas.
- Preparation of the shipping instructions or documentation.
- Moving the container to the shipping dock.

ACTIVITY DATA SHEET

2.0 ACTIVITY DESCRIPTION (CONT)

Flow Number: 20.0

Including travel time, this five-step procedure takes approximately 2-1/2 days per set of three experiments. Shipment of four sets (including overlap periods) will require a total of approximately 5-1/2 days. This activity is performed entirely in parallel to the Spacelab refurbishment efforts and does not represent any additional serial processing time in the Spacelab test and operations flows.

BLOCK 21.0 REFURBISH SUPPORT SYSTEMS & EM/SM SHELLS

```
***1***2***3***4***5***6***7***8***9**10 WORKING DAYS

****  DRAIN, FLUSH, DRY & CAP COOLANT SYSTEMS
    ********  REMOVE/REPLACE SUPPORT EQUIP AS REQUIRED
    ********  REM CABLES/FLD LINES/BKT'S NOT REQUIRED FOR NEXT FLT
            **  VERIFY OPERABILITY OF FLD SYS COMPONENTS
              **  EXAMINE CABLES/CONNECTORS/FLD LINES & REPAIR
                ***  REFURB & VERIFY OPER OF AIR REVITALIZATION SYS
                   ***********  REFURB & VERIFY OPER OF IMS COMPONENTS
                              *  INSPECT, CLEAN, POLISH & ALODINE EM/SM MATE SURFACES
                              *  VAC/CLEAN INTERIOR & EXTERIOR OF EM/SM SHELLS
                               **  RETOUCH/PAINT EM/SM SHELLS WITH THERMAL PAINT
```


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ACTIVITY DATA SHEET

1.0 ACTIVITY IDENTIFICATION

Functional Flow Number: 21.0 Applicable Concepts: ALL

Title: Refurbish Support Systems and SM/EM Shells

Principal Elements: Support Module (SM) and Experiment Module (EM) Shells

2.0 ACTIVITY DESCRIPTION

At the conclusion of the mission, the subsystems of the SM and the structural shells of both the SM and EM will be completely checked out and refurbished. This activity will be a checkout and not a design verification. The checkout will not involve an exercising of the complete subsystem (all assemblies) over the anticipated performance range of the components and sensors. The checkout will consist of four parts:

1. Testing - The actual checking of selected components and sensors to verify functional performance (some pumps, regulators, power conditioners, etc.).
2. Analysis of previous flight performance.
3. Similarity of equipment to equipment used on previous missions (batteries, filters, etc.).
4. Inspection (lights, caution/warning annunciators, panel display connections).

The initial activity of this block will be the removal of support equipment, cabling, fluid lines and brackets not required on the next flight. The next activities will be the refurbishment of each of the subsystems in the support module (information management, thermal control, electrical power, attitude control, and air revitalization. This refurbishment will have to be completed prior to support module checkout. "Refurbishment" is intended to mean replacement of expendables or degraded parts with components that are either new or have been through a maintenance cycle. These replacement components would have been checked out prior to installation. For example, TV cameras will need periodic maintenance. After 200 hours of operation, the vidicon image tube must be replaced and the entire focusing, deflection, gray-scale, etc., must be tuned. This is a bench operation; it is not effective to do this tuning in-place. It can be more easily and efficiently accomplished in an electronics lab. The entire camera would be removed and replaced with a refurbished spare. The actual

ACTIVITY DATA SHEET

2.0 ACTIVITY DESCRIPTION (CONT)

Flow Number: 21.0

repair, test and certification of components and subassemblies is a bench operation. It is considered to be off-line, and not a part of the SM test and checkout operations flow.

After each mission, the SM subsystem will not be completely disassembled, checked and then reassembled--only those components that have failed on previous missions, or have reached the replacement stage because of the number of cycles they have performed, or the total elapsed time they were used, or are expendables that are replaced after each flight. Within this concept, refurbishment and modification shall be on a remove-and-replace basis.

The refurbishment and reconfiguring of the SM is scheduled to take slightly more than eight serial days to accomplish (1 day = 8 hours/single shift). It will be accomplished in the following order.

1. Removal of support equipment, cabling, fluid lines and brackets not required on the next flight.

2. Servicing of the thermal control coolant loops by draining and flushing the lines, coldplates, and circulating pumps of support equipment not removed; capping or connecting flow paths or removing equipment.

3. Examining all cabling, connectors, fluid lines and connections--performing necessary repairs.

4. Checking operation of air revitalization assemblies.

5. Refurbishing and verifying operation of the following IMS components:

   - Tape recorders - Clean heads, lubricate motors and bearings, replace tape guides, and install new tape.
   - TV camera - Replace vidicon and clean lenses.
   - Printer-plotter - Replace ribbon, clean platen and add paper.
   - Camera-film - Replace film and clean lenses.
   - Experiment-unique displays and controls - TBD

   Modifying the following IMS equipment:

   - Some remote acquisition unit (RAU) interconnections to sensors.

ACTIVITY DATA SHEET

2.0 ACTIVITY DESCRIPTION (CONT)

Flow Number: 21.0

- Computer software
- Some caution and warning instrumentation.
- Experiment-unique panels and wiring.

After each of the subsystems has been refurbished, then the SM test and checkout operations will be performed. GSE power and cooling will be connected to the SM to energize the subsystems and test them to verify that they are capable of supporting the next mission. The IMS will be used to check out the other SM subsystems. The IMS will first go through a series of seven steps prior to its use for the checkout of the SM subsystems.

1. Computer Self-Test
   - Standard program stored in memory
   - Test problem, error checks, and diagnostic check
2. Instrumentation Self-Test
   - Additional standard program exercises data bus and RAU's.
   - Interrogate each RAU for one "status check" (which is a built-in test function in the RAU).
3. Command/Control Verification
   - Computer program is used to interpret manual keyboard function.
   - Commands are input via controls, operations simulated and results displayed for evaluation.
4. Peripheral Equipment Verification
   - Computer programs to exercise data recorders, printers, plotters, etc.
   - Utilize test signals and simulated data to verify operations.
5. Check List
   - Operational status check
6. Displays/Control Verification
   - Simulation of experiment displays and controls with GSE.

ACTIVITY DATA SHEET

2.0 ACTIVITY DESCRIPTION (CONT)

Flow Number: 21.0

7. Orbiter Umbilical Verification

- GSE simulation of the singals (caution/warning, voice data) that cross the Orbiter/Spacelab interface via an umbilical.
- Orbiter simulated by GSE.
- Wiring check of signal paths.

This completes the IMS verification. The IMS is now ready to be used to verify the remainder of the SM subsystems as shown in the table below.

The final two steps of this activity are: (1) vacuuming and cleaning of the interior and exterior of the SM and EM shell, examination of the mating surface of EM shell and aft bulkhead for corrosion or stress cracks, cleaning, polishing and anodining the mating surfaces; and (2) preparing for move and mating with the EM experiment rack/floor assembly, painting/retouching SM external surfaces with thermal paint, and retouching interior surfaces of SM. This completes the refurbishment and checkout of the SM and EM shell.

Assembly/Component	Checkout/Verification Requirement
THERMAL CONTROL	
Coldplates (three parallel systems), pumps, controls and displays, isolation valves, flow controls, temperature monitors, and pressure monitors	The SM thermal control components will have to be connected to the GSE coldplate supply system, and the pumps exercised through on/off cycles. The pressure transducers used in conjunction with the pump speed will be utilized to measure pump inlet and outlet pressure and determine system line losses. Temperature transducers will be checked to determine coldplate efficiency. The displays will be CRT pages and will be verified during IMS command control verification. Estimated time for verification is 2 hours. This includes connection to the GSE equipment, operation of the SM pumps and checks on the cooling capacity at the various coldplates.
ATTITUDE CONTROL	
SM Independent attitude sensors	Check electrical power continuity to the attitude sensors and a continuity check from the sensor data return line to the SM IMS. Input a know voltage to the gyros and determine that they precess the proper direction and amount. This test voltage will require IMS computer support. The logic commands attitude/rate displays will be verified during the IMS command/control verification. Estimated time for gyro checkout is 2 hours.
Attitude/Rate Display SM and Shuttle data	Verification that the displays are programmed to be handled by the SL IMS will be completed during IMS command/control verification.
Pallet 3-axis gimbaled platform, sun sensors, star tracker set, horizon scanner, and magnetic field detector	When these equipments are installed on the pallet there is a requirement for GSE equipment to stimulate the sensors and receive the data outputs to be used in conjunction with simulated Orbiter inputs to derive an integrated set of Orbiter/pallet position parameters. Verification requires Orbiter simulator for Shuttle position and return data. Estimated time for test is 4 hours.

-continued on Sheet 5 of 5

ACTIVITY DATA SHEET

2.0 ACTIVITY DESCRIPTION (CONT)

Flow Number: 21.0

Assembly/Component	Checkout/Verification Requirement
AIR REVITALIZATION	
SM	
Pressure (14.7 psia), O_2+N_2 system, positive pressure relief; leak rate	Operating pressure, 14.7 + X psia--this will be verified by checking the SM and EM leak rates, and verifying operation of atmospheric makeup system (see gas storage). Check positive pressure relief valve operation. Estimated time for valve check is 1 hour; leak checks, TBD hours.
Temperature (65 to 85 F selectable) and humidity	Check cabin Hx and fan, cabin coolant loop (water) flow rates, pressures; verify operation of equipment Hx and fan. GSE equipment required to simulate Orbiter radiator interface (payload Hx). This is the same equipment utilized for the thermal control coldplate verification and checkout. Also required are visual inspections of the water storage from the humidity Hx. These inspections are to check connections and quantities where required. Estimated time for test and checkout is 4 hours.
Gas storage (O_2, N_2)	Mechanical check of bottle insulation and purity monitor check. Check flow control devices. Check interface with the CO_2 counter or measurement device to ensure that proper mixture ratio can be maintained.
Air circulation - fans; habitable area (48 cfm); equipment racks - forced air	Fans, on/off test verification that operational status still valid; measure air movement rate 48 cfm $\pm$ X cfm; forced air ducting, (remove and replace filters--see contamination control).
Contamination control (100,000 class); odor control; charcoal beds and HEPA filters	HEPA filters/charcoal beds: These equipments should be treated as expendables and replaced prior to each mission. Real-time contamination monitoring system (RTCM) would need to be checked if utilized.
Fire control N_2 bath (module and rack); exhaust to space; portable extinguishers; smoke/heat sensors	Checklist. Verify quantity of payload N_2 sufficient for normal (atmospheric makeup) and contingency modes plus possible SM repressurization; check SL atmosphere dump to space value; inspection of portable extinguishers and smoke/heat sensors.
ELECTRICAL POWER	
Dual battery pack (30 kwh) Dual ac regulators	A ground power source will be used to simulate Orbiter power. The ground source will duplicate Orbiter voltage levels and quality. This will be used to verify the voltage regulators and power conditioners. Test time estimated to be 0.5 hour.
Power conditioners	Power distribution control check. Verify that power can be routed through the SM to various EM and pallet locations. Estimated time for verification is 15 minutes.
Power distribution controls/displays	Check SM power distribution lines to EM. Lighting check--turn lights on/off. Estimated time is 10 seconds.
Voltage/amp/freq/phase displays	Battery pack--voltage level check--can be performed by keyboard selection from IMS console (10 seconds); there will also be a visual inspection of the installation of the batteries. NOTE. The power regulation, conditioning and distribution subassemblies are the only ones that can be checked out or verified on the SM. All displays of voltage, amperage, frequency, power distribution, etc., will be verified during the IMS checkout of the CRT page displays.

BLOCK 22.0 POST REFURBISHMENT RACKS/PALLET SHIPMENT

```
***1***2***3***4***5***6***7***8 WORKING DAYS

**  CONNECT LIFTING DEVICES TO RACKS/PALLET
  **  LOAD RACKS/PALLET IN SHIP CNTR, LOAD ON XPORTER, SECURE & REM LIFT DEVICES
    *  INSTALL SHIP CNTR PORT PRESS UNIT & ACTIVATE
     **  MOVE SHIP CNTR TO AIR CARRIER LOADING SITE
      **  LOAD SHIP CNTR ON AIR CARRIER
        ********  RACKS/PALLET ENROUTE TO USER FACILITY
                *  RACKS/PALLET ARRIVAL AT USER FACILITY
                 **  OFFLOAD SHIP CNTR & XPORT TO EXPMT INSTALLATION AREA
                   **  REMOVE SHIP CNTR CVR & PRESS UNIT
                     **  CONNECT LIFT DEVICES & REMOVE RACKS/PALLET FROM SHIP CNTR
                       *  MOVE RACKS/PALLET INTO DOLLY/STAND & REM LIFT DEVICES
                        **  REMOVE ACCESS/INSP PANELS & CONDUCT R/I
                        **  INSTALL PROTECTIVE CVR'S/PADS
                          *  REINSTALL ACCESS/INSP PANELS
```


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ACTIVITY DATA SHEET

1.0 ACTIVITY IDENTIFICATION

Functional Flow Number: 22.0 Applicable Concepts: III

Title: Post-Refurbishment Rack/Pallet Shipment

Principal Elements: Racks, Pallet, Shipping Canister

2.0 ACTIVITY DESCRIPTION

The tasks associated with this block are almost identical with those of Block 18.0; there is only one noteable difference. This block describes a move that follows the repair and refurbishment operations, while Block 18.0 concerns a move that precedes this refurbishment. Therefore, the only activity that will vary is the final one. In this block there is no need to conduct a post-shipping receiving inspection (R/I) because the racks and pallet have just completed refurbishment. Therefore, only the normal quick-look R/I will be performed. Its function will be to establish that there has been no damage caused by the shipment.

The steps of this activity are as follows.

- Movement of the racks/pallet to the shipment area.
- Connecting of lifting devices and loading the racks/pallet into the shipping containers (canister).
- The shipping container will have a portable pressurization unit installed and activated.
- The shipping container will be taken to the loading site and loaded into an air carrier (Boeing 747).
- Two days (enroute) of serial time for the shipment to the launch site.
- Arrival at the refurbishment center, and off-loading of shipping container and transporter to refurbishment center.
- Racks/pallet will be off-loaded into a work dolly and the lifting devices removed.
- Protective pads and covers will be installed.
- Access/inspection panels will be removed and an R/I conducted.
- The final task will be the reinstalling of the access/inspection panels.

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PART 2. PALLET-ONLY

This part of Appendix D contains the activity data sheets for the pallet-only concepts. These descriptions were developed in the same manner as those for the complete Spacelab, and they also represent the details of the test and operations activities associated with the entire ground processing operations of the pallet-only hardware and experiments. There are 19 activities developed and they follow the processing cycle of pallet/igloo operations from shipment of experiments (Functional Flow No. 1) and their related auxiliary equipment from the user/PI laboratories to the experiment integration area. They also include the operations of experiment installation (2.0), experiment checkout and integration (4.0), and Spacelab integration (9.0). The activity data sheets (ADS) conclude with the activities that relate to the post-mission operations through the refurbishment of the pallet, igloo and experiments subsequent to their being used on another mission.

In order to correlate these activities and the appropriate detailed flows to which they relate, they must be referenced back to Volume II, Section 4.2, Integrated Flow. The timelines for all three concepts are also included in that same section of Volume II.

To facilitate the use of these activity data sheets, Table D-2 has been included. Each ADS has the concept effectivity indicated.

Table D-2. Pallet-Only Processing Concepts

Concept	Owner		Integration Site	
	Pallet	Igloo*	Experiment Equipment	Spacelab
VI	IC	LS	User	LS
VII	IC	LS	IC	LS
VIII	User	LS	User	LS

*Support system igloo and equipment--experiment igloos are owned by the pallet owner.

PALLET ONLY - CONCEPTS VI/VIII - BLOCK 1.0 EXPERIMENT SHIPMENT

*******1*******2 WORKING DAYS

**** TRANSFER EXPMTS FROM USER/PI LAB TO EXPMT INTEGRATION AREA
**** CONDUCT EXPMT/SUPPORT EQUIPMENT R/I

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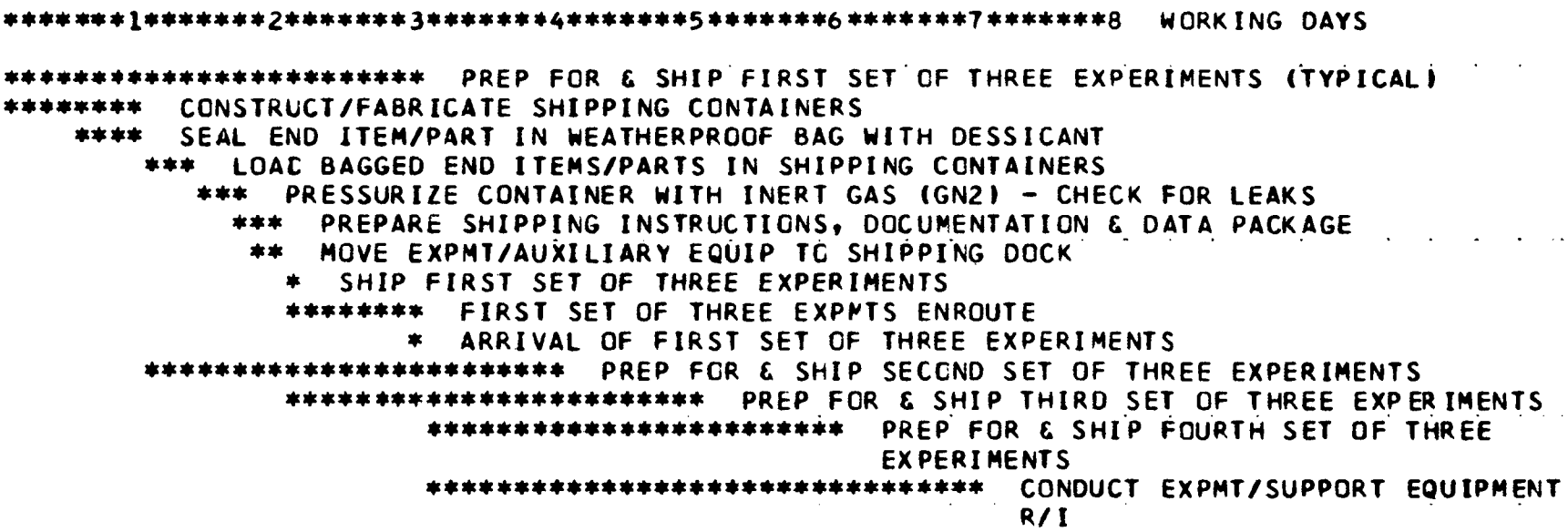
PALLET ONLY - CONCEPT VII - BLOCK 1.0 EXPERIMENT SHIPMENT



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ACTIVITY DATA SHEET

1.0 ACTIVITY IDENTIFICATION

Functional Flow Number: 1.0 Applicable Concepts: VI and VIII

Title: Experiment Shipment

Principal Elements: Experiments and Auxiliary Equipment

2.0 ACTIVITY DESCRIPTION

This activity involves the transfer of experiments and their related auxiliary equipment from the user/PI laboratories to the experiment integration area. Since in these two concepts the installation of experiments onto the pallet, or into experiment igloos, will occur at the user's facility this transfer function is a relatively short and simple operation, involving the movement of experiments and auxiliary equipment over short distances and has been estimated to require only four hours of serial processing time.

Within this activity there are no estimates for the development or construction of packaging or shipping containers. The packaging containers for instruments and/or auxiliary equipment will be the responsibility of the principal investigator (PI).

This activity will include a receiving inspection (R/I) of the experiment and support equipment. Since each piece of equipment will be checked as a part of the installation activity, this R/I is merely a top-level scanning and inspection that all necessary items have been received and were not damaged during shipment/transport from the user/PI lab.

The tasks involved in the block can be accomplished far in advance of the initiation of a given mission and need not be a constraint on the activities related to the preparation of the pallet, igloos or support systems; therefore, the serial processing time for this block has not been added to the total time for the applicable concepts involved in this aspect of the study analysis.

ACTIVITY DATA SHEET

1.0 ACTIVITY IDENTIFICATION

Functional Flow Number: 1.0 Applicable Concepts: VII

Title: Experiment Shipment

Principal Elements: Experiments and Auxiliary Equipment

2.0 ACTIVITY DESCRIPTION

This activity covers the preparations for shipment and transportation of the pallet-only experiments and auxiliary equipment from the user and/or Principal investigator (PI) to the integration center (IC). All experiments and auxiliary equipment required for the referenced mission will be packaged for shipment to the IC. The selected transportation mode will be via air carrier.

The time estimates were developed by determining the task requirements and estimating the times for logical experiment sets. These time estimates were applied to the number of experiment sets in the reference pallet-only payload. Preliminary analysis indicated that the experiment groups should be parepared in sets of three. The following are the tasks that must be performed for each of the four sets of experiments.

- Construct/fabricate shipping containers - Shipping containers will be constructed for each piece of experiment and auxiliary equipment.
- Seal end item/part in weather-proof bag with dessicant - All equipment will be wrapped to ensure that there is no exposure or contamination during shipment.
- Load in containers - After sealing in the weather-proof bags, all end items will be placed in their shipping containers and all restraints and shock/vibration recording devices will be connected.
- Pressure containers - Each container will be sealed and pressurized with an inert gas for environmental protection. After pressurization, leak checks will be conducted.
- The activity also includes the preparation of shipping/handling instructions. This documentation will be completed for each end item and accumulated as a data package for each mission.

ACTIVITY DATA SHEET

2.0 ACTIVITY DESCRIPTION (CONT)

Flow Number: 1.0

Applicable Concept: VII

- The next step is the transport of the experiment and auxiliary equipment to the shipping dock, and the shipment of the first set of three experiments.

These five steps will be performed three more times for the remaining nine experiments of the reference mission. For an overview of the time sequencing of these steps, see the functional flow diagram for Block 1.0.

Since the steps involved in this block can be accomplished far in advance of the initiation of a given mission, and since they need not be a constraint on the activities related to the preparation of the pallet, igloos or support systems, the serial processing time for this block has not been added to the total time utilized in the study analysis.

Block 1.0, Experiment Shipment, is concluded with the conducting of a receiving inspection of the experiment and support equipment upon receipt at the integration center (IC). Each experiment will be unpacked in the area assigned to the PI's per the facility requirements of the ICD's. The receiving inspection will be conducted by the PI's and/or his authorized representative, assisted by integration site personnel as required.

Inspection operations to be performed shall include, but not be limited to the following items:

- Visual inspection of each component for damage that may have occurred during shipping.
- Checks of transportation accelerometers along with the humidity and temperature monitors (if used) to assure that no out-of-tolerance conditions occurred during transportation.
- Check of protective bags or enclosures to ensure that equipment cleanliness had been maintained during shipment.
- Review of all accompanying documentation, installation drawings, and test procedures to assure completeness.

Any experiment/equipment which necessitated partial disassembly to facilitate shipment will be reassembled at this time by the PI's. Any realignment or functional retest required to verify the hardware integrity will also be performed prior to the formal turnover, to the integration site personnel, for subsequent installation.

ACTIVITY DATA SHEET

2.0 ACTIVITY DESCRIPTION (CONT)

Flow Number: 1.0

Applicable Concept: VII

After completion of these steps, the experiments and their related sensors, electronics, cables, test aids, and instrumentation are ready for installation on the pallet, canister, or in the Payload Specialist Station (PSS) simulator.

HANDLING REQUIREMENTS. Almost all of the above mentioned constraints including g-loading will generally be satisfied by the design provisions of the shipping container plus specific instructions on handling. Small containers (less than 75 lb) will be considered as being capable of being handled by one or two men. The heavier experiment hardware will require cranes, hoists or forklifts for unloading from the aircraft. A truck or other means of transportation will be required for transfer to the experiment integration area.

PALLET ONLY BLOCK 2.0 EXPERIMENT INSTALLATION (PALLET/IGLOO)

```
*********1*********2*********3*********4*********5  WORKING WEEKS

**  PREPS FOR INSTALLATION OF EXPERIMENTS/SUPPORT EQUIPMENT
  **********  INSTALL EXPMT/SUPPORTEQUIP CABLING,LINES & BRACKETS ON
              PALLET/IGLOO
  **  NAVIGATION
    ********  EARTH OBSERVATION
            ********  PHYSICS & CHEMISTRY
                    *  ENVIRONMENTAL EFFECTS
                     *  COMPONENTS & SYSTEMS
                      ***********  INSTALL EXPERIMENTS & SUPPORT EQUIP ON PALLET & IGLOO
                      ***  NAVIGATION
                         **  ENVIRONMENTAL EFFECTS
                           ***  EARTH OBSERVATION
                              **  PHYSICS & CHEMISTRY
                                **  COMPONENTS & SYSTEMS
                                  **  PERFORM CABLING CONTINUITY CKS AT P/IGLOO INTERFACES
                                    **  MATE P/IGLOO--INSALL ATTACT BOLTS & TORQUE
                                      **  CNCT FLD LINES - VERIFY I/F CONNECTIONS
                                        **  POST ASSY CLEAN UP - PREP FOR P/IGL MATE WITH
                                            S/S IGL,ORB SIM & AUX GSE
```


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ACTIVITY DATA SHEET

1.0 ACTIVITY IDENTIFICATION

Functional Flow Number: 2.0 Applicable Concepts: All

Title: Experiment Installation (Pallet/Igloo)

Principal Elements: Experiments/Auxiliary Equipment/Pallet

2.0 ACTIVITY DESCRIPTION

Task description and schedule time estimates for experiment and support equipment installation on the pallet and experiment igloos are based on the following:

- The experiment instruments and support equipment have been functionally tested at the principal investigator's (PI's) or user's laboratory prior to their arrival at the experiment integration area, and all parameters have been verified to be within desired design limits.
- Pallet and experiment igloos have been refurbished, reconfigured, and checked out as described in functional flow Block 18.0, Pallet-Only Concepts, and are available in the experiment integration area.
- Each experiment and piece of support equipment has undergone receiving inspection (R/I) operations at the integrator's facility after arrival and prior to installation on the pallet or experiment igloos or PSS simulator.

Basically, the experiment installation activity (Block 2.0) involves four major tasks.

1. Installation of experiment support equipment--cabling, lines and brackets on pallet sections and the experiment igloos. These mechanical operations are precursors of the experiment installations. They should be completed prior to the initiation of experiment installation while access problems are minimal.
   - Preparation of pallet/igloo for installation of experiment and support equipment.
   - Installation of support items such as brackets, fluid lines, and cabling.
   - Location and alignment of critical support brackets, including accurate verification of the installation of the supports.

ACTIVITY DATA SHEET Sheet 2 of 4

2.0 ACTIVITY DESCRIPTION (CONT) Flow Number: 2.0

After the pallet/igloo has been positioned in the experiment installation area and demated, the attach bolts are removed at the pallet/igloo interfaces. The two units are separated and the lines/connectors are capped/bagged. The experiment igloo shells are then removed to facilitate access for experiment installation.

Existing pallet/igloo cable runs and utility lines will be repositioned and reworked for the requirements of the specific mission. There will be very few "standard" utilities' accommodations for experiments on either the pallet sections or the experiment igloo. New lines dedicated to specific experiments for caution and warning, controls, data signals, and display outputs will also be added. There will be common lines and plumbing for power, data bus and thermal control.

This step would also include the installation of the extended digital data base (XDDB) equipment such as the remote acquisition control units (RACU's) and the bus interface units (BIU's). In general, the number of RACU's will be determined by the density of the measurement points and the command signals in each area.

Coldplate plumbing manifolds will be installed; the coldplate pads will be added when the equipments are mounted.

2. Experiment installation. Installation and alignment/adjustment of the experiments are performed sequentially by experiment. The times for this activity are defined primarily by accessibility of pallet space and/or experiment igloos and, secondly, by the manpower estimates for this task. Therefore, the application of twice the manpower estimated for these tasks would not reduce the serial processing times by 50 percent. The installation will be performed prior to mating the pallet/igloos with the simulators to further maximize accessibility. The installation of experiments is presumed to be accomplished serially by discipline on both the pallet, igloos and the PSS simulator. Pallet installations may require cranes, hoists, etc., to handle the components. Alignment devices such as theodolites, autocollimators, bench marks, mirrors, levels and targets will be used to verify mechanical alignment. Coldplate pads will be added as required when the equipment is mounted. As each experiment hardware package or rack is mechanically attached, an electrical bonding check will be performed. This check is necessary to assure that an adequate and common ground exists between the experiment and the pallet, igloo or simulator. The next step will be the completion of the mechanical connections (bolting to rack or bracket, and connection to coolant loops) plus the installation of

ACTIVITY DATA SHEET Sheet 3 of 4

2.0 ACTIVITY DESCRIPTION (CONT) Flow Number: 2.0

protective covers where required. Experiment hardware installation will vary according to the complexity and size of each experiment. For the detailed installation time requirements for each experiment, see Appendix A.

The next step of the installation function will be an end-to-end continuity check of all wiring at each experiment connector. The wiring checks are verified with plugs out by tracing the wire list pin-to-pin, ehcking it against the electrical ICD. As each plug is verified, it is inserted in the mating connector on the experiment.

The final step is an inspection of all fluid line connections.

Installation of each experiment shall be controlled by the following documentation:

- Mechanical Interface Control Drawing ABC
- Electrical Interface Control XYZ
- The experiment Interface Control Document (ICD)
- Installation/Handling Procedures

After installation, Quality Control shall verify the following:

- Proper installation and alignment of experiments per drawings.
- Proper electrical power subsystem interfaces with the pallet/igloo/PSS simulator, and with each experiment assembly per drawings.
- Proper interface with the Information Management System (IMS) for each experiment per ICD's.

3. Continuity checks. Cabling continuity checks at the pallet/igloo interfaces are performed. Prior to the physical mating of the pallet/igloo and the Orbiter simulator set, it will be necessary to perform a continuity check of the wiring connections at the interface bracket. This check will complete the end-to-end checks of all pallet and igloo wire harnesses, experiment hardware connector pin assignments, and pallet/canister/Orbiter wiring interfaces. The wiring checks are verified by tracing the wire list, pin-to-pin. Note that "end-to-end" does not imply disconnecting the experiment unit equipment cable; this was previously verified during individual experiment installation.

After completion of the wiring continuity checks, all fluid lines and connections will be checked to assure that there are no leaks in

ACTIVITY DATA SHEET

2.0 ACTIVITY DESCRIPTION (CONT)

Flow Number: 2.0

any components of the fluid systems. GSE sniffers and leak detectors will be utilized. These devices provide a rapid means of detecting leakage of pallet/igloo fluid systems.

4. Cleanup operations. Post-assembly cleanup and preparations for mating of pallet/igloo to the support system igloo simulator and the Orbiter simulator are the final activity steps.

   This activity disconnects and/or removes from the area, the auxiliary GSE used for the installation, alignment, wiring checks and leak checks.

   Protective pads and enclosures are secured; umbilical and other interconnects are secured; and the position/orientation of the pallet dolly is modified (if needed) and secured to the floor. An installation discrepancy report is prepared if required.

PALLET ONLY BLOCK 3.0 CONNECT & C/O SUPPORT SYS IGLOO/ORBITER SIMULATOR SET

```
*******1*******2*******3*******4*******5*******6  WORKING DAYS

********  POSITION/MOVE GSE IN P/IGL C/O AREA (S/S IGL/ORB/PSS SIM SETS
         ********  VERIFY SIMULATOR SETS/FACILITY INTERFACES
                  ****  CONNECT SIMULATOR SETS TO FACILITY INTERFACES
                  ****  VERIFY SS IGLOO SIM SET ELEC/MECH CONNECTIONS AT P/IGL I/F'S
                      ****  CONNECT SS IGLCO SIM/ORB SIM SETS TO PALLET/IGLOO I/F'
                          **  POWER UP COOLANT LOOPS - VERIFY FLD FLOW THROUGH GSE & P/IGL
                            **  PERFORM BUS ISOLATION TESTS OF PALLET/IGLOO
                              **  CONDUCT PRE-PWR SW LIST TO VERIFY SW & CONTROL SETTINGS
                                *  POWER UP P/IGL ELEC SYS EXCLUDING COMPUTER FUNCTION
                                ***  CONDUCT POWER DISTRIBUTION CHECKS
                                  *  VERIFY C/W INDICATORS - PUSH TO TEST CIRCUITR
                                   *  POWER UP CONTROL CONSOLE & COMPUTER FACILITY
                                   *  CONDUCT COMPUTER & INSTRUMENTATION SELF-CHECKS
                                    ****  VERIFY COMPUTER COMMAND & CONTROL CAPABILITY
                                      **  VERIFY OPER OF IMS PERIPHERAL EQUIP, GND DATA
                                          BASE COMPATIBILITY & AUX EQUIP
                                        *  POWER DCWN P/IGL SYSTEM & ALL GSE
                                        ********  CONDUCT EXPMT INTEG READINESS REVIEW (PI
                                                  PARTICIPATION)
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ACTIVITY DATA SHEET

1.0 ACTIVITY IDENTIFICATION

Functional Flow Number: 3.0 Applicable Concepts: All

Title: Connect and Check Out Igloo/Orbiter Simulator Set

Principal Elements: Support System Igloo Simulator and
Orbiter Simulator Set

2.0 ACTIVITY DESCRIPTION

Primarily, this operation consists of the electrical and mechanical connection of the Orbiter simulator set and the support system igloo simulator to the pallet/experiment igloos. It also includes simulator self-test to verify operability. These two simulators are required in the pallet-only concept because there are two major flight elements that will not be utilized in the test and checkout of the mission readiness of the experiments, pallet and experiment igloos:

- Orbiter (including PSS station) interface
- Support system igloo interface

In order to supply the necessary functions that these pieces of equipment provide, two simulators are utilized in the program during this functional block.

- Orbiter Simulator Set (includes PSS simulator--both functional interfaces and fit/form). The Orbiter simulator set consists of a computer, a display/control console, coolant system, payload specialist station (PSS), power conversion equipment, and extended digital data bus (XDDB) controls. The simulator computer may be a copy of the PSS computer, some other miniprocessor, or a buffer translator interfacing with the ground data base (GDB).

The console should include the same keyboard, page format display, and function-select switches as found in the Orbiter console. Peripheral recorders and auxiliary equipment may be included. Conditioned air and lighting, where required, are not physically integrated with the Orbiter simulator set.

PSS equipment consists of: caution/warning electronics panel, TV monitor panel, digital recorder, recorder control panel, ACS control, audio/visual recorder, CRT symbol generator panel, and subsystem RAU control.

- Support System Igloo Simulator. The support system igloo simulator set consists of equipment to simulate the following.

ACTIVITY DATA SHEET

2.0 ACTIVITY DESCRIPTION (CONT)

Flow Number: 3.0

- Environmental control system cooling capability for equipment mounted on the pallet or in igloos.
- Data management system - the support system equipment will be simulated with computers, input/output units, mass memory, RAU's, and C/W logic.
- Electrical power system - equipment for power conversion, experiment inverters, an emergency battery, power control box, secondary power distribution, and a subsystem inverter will be provided.

The steps to be completed in this task are as follows.

1. Position and connect Orbiter and support system igloo simulator sets and auxiliary GSE. This activity involves the pre-mate preparations and physical connection of the Orbiter simulator set and the support system igloo simulation set to the pallet and experiment igloos. The following tasks are necessary in the implementation of this task.
   - Move and position the two simulator sets and auxiliary GSE (power, cooling, etc.) to the pallet checkout area.
   - Verify electrical and mechanical connections, perform continuity checks of the electrical connectors, and complete the connection of the GSE/facility interface.
   - Verify the electrical and mechanical continuity of the two simulator sets and connect them to the pallet and igloos.

   Along with the completion of these tasks, it is presumed that the computer support required has been verified and is ready for utilization in the Orbiter simulator set; and that it has been properly configured to support the specific payload configuration being tested.

2. Power up and check out Orbiter simulator set and support system igloo simulator set (excluding computers). This task involves the power-up and pre-test checkout of the two simulator sets, except for their computers. It will require the following steps to be successfully completed.
   - Power up the coolant loop and verify coolant flows through the GSE/pallet/igloo.
   - Perform pallet/experiment igloo bus isolation tests.
   - Conduct pre-power switch checkout verifying the switch and control settings.

ACTIVITY DATA SHEET

2.0 ACTIVITY DESCRIPTION (CONT)

Flow Number: 3.0

- Power up the pallet/experiment igloo electrical system portion of the Orbiter and support system igloo simulator sets--excluding computer functions.
- Conduct power distribution checks.
- Verify caution/warning (C/W) indicators, lights, signals, etc.

3. Power up and check out computer portion of simulator sets. The successful completion of these steps are necessary to establish the operating performance of the computers prior to power-up of the experiment systems. The events involved in this task are:
   - Power-up of the control console and the computer facility portion of both simulator sets.
   - Conducting computer/instrumentation self-checks.
   - Verifying computer command/control capability.
   - Power-down the electrical/mechanical systems and all GSE.

4. Conduct experiment integration readiness review. After verifying the operating performance of the installed GSE and the Orbiter and support system igloo simulators, an experiments integration readiness review is conducted. Participation of the PI's and other concerned parties is necessary to verify that all systems are ready for the experiment integration test. Items to be reviewed include all previous systems data, discrepancies, configuration and anomalies. Review of such data and any outstanding open items (configuration shortages and checkout procedure readiness) that could affect the test results must be approved or dispositioned before the individual and integrated experiment system tests can be initiated.

PALLET ONLY BLOCK 4.0 EXPERIMENT CHECKOUT & INTEGRATION

```
****1****2****3****4****5****6****7****8  WORKING WEEKS

*  TEST TEAM CALL TO STATION FOR EXPMT C/O AND INTEGRATION TESTS
*  CONDUCT SW LIST VERIFICATION OF POSITION AND CONTROL SETTINGS
*  POWER UP P/IGL SIM, ORBITER SIM SETS & PALLET/IGLOO
*********  CONDUCT INDIVIDUAL EXPMT C/O BY DISCIPLINE
          **************** CONDUCT EXPMT'S INTEGRATED SYSTEMS TESTS
                        ******** CONDUCT EMC/RFI TESTS & ANALYSIS
                                *  POWER DOWN SIMULATORS, GSE & PALLET/IGLOO
                                 *  DATA REVIEW
                                  *  WORK DISCREPANT ITEMS
                                  *  SYSTEM RETEST
                                   *  NASA ACCEPTANCE REVIEW
```

ACTIVITY DATA SHEET

1.0 ACTIVITY IDENTIFICATION

Functional Flow Number: 4.0 Applicable Concepts: All

Title: Experiment Checkout and Integration

Principal Elements: Pallets and Igloos

2.0 ACTIVITY DESCRIPTION

Utilizing the simulator sets described in Block 3.0 as the checkout equipment, each experiment equipment set is exercised by discipline through all modes and configurations to verify the functional status of each experiment. After individual experiment checkout, those experiments that would operate concurrently during the mission are operated together to ensure that no incompatibility exists. An EMC/RFI check is performed to assure conformance of the pallet and experiment igloos with Orbiter system requirements. Crew training is augmented by conducting abbreviated mission simulations in parallel with the integrated experiments checkout. This effort will familiarize the flight personnel with the mission timeline they will be utilizing in the mission.

Following power-down from the experiment integration tests, a brief data review will be held, discrepancies identified, dispositioned, worked and retested prior to final NASA acceptance review.

The following steps are accomplished during the completion of this block:

Conduct individual experiment checkout by discipline. This activity involves a functional checkout of each individual experiment installed on the pallet/canister. This testing is performed to establish the operational capability of the individual experiment prior to the experiment integrated systems testing. These tests are designed around the fact that the development and acceptance phases have previously been completed. They are established to demonstrate operational capability, and not as a quantitative evaluation of system performance.

Tests will be performed by discipline on an individual experiment basis. The general steps involved in the functional checkout procedure are as follows.

- Set up the experiment equipment and activate the support equipment.
- Activate the control and display console.

ACTIVITY DATA SHEET

2.0 ACTIVITY DESCRIPTION (CONT)

Flow Number: 4.0

- Check out the control and display console concurrently with the checkout of the experiment equipment.
- Verify the mechanical operation of the pallet-installed equipment.
- Verify the operation of the experiment sensors on the pallet.
- Verify the operation of the equipment in the igloo.
- Check out the miscellaneous support and auxiliary equipment.
- Verify the data processing recording concurrently with the checkout of the equipment on the pallet and igloo.
- Power down and secure the equipment.

For the detailed test and checkout requirements on each experiment, see Appendix B.

The time to functionally verify each experiment of Payload 1 is estimated as follows:

Discipline	Experiment		Time (hr)
Navigation	NV-1	Microwave Interferometer	7.50
	NV-2	Autonomous Navigation	9.50
Earth Observations	EO-1	Lidar Measurements	5.25
	EO-4	Radiometer	6.00
	EO-7	Search and Rescue Aids	7.75
	EO-8	Imaging Radar	7.25
Physics and Chemistry	PH-2	Barium Cloud Release	9.25
	PH-4	Neutral Gas Properties	6.75
Environmental Effects	EN-1	Micro-Organism Sampling	2.00
	EN-3	Non-Metallic Materials	3.75
Components and Systems	CS-3	Contamination Monitor	2.50

These estimates are predicated upon (1) initial equipment alignment being performed as part of the installation; (2) the cameras (pre-loaded) containing test film; (3) the ground support equipment being previously tested, verified and validated; and (4) the experiments and experiment support equipment being functionally tested and verified during their individual experiment acceptance testing prior to their arrival at the integration site.

ACTIVITY DATA SHEET

2.0 ACTIVITY DESCRIPTION (CONT)

Flow Number: 4.0

Conduct experiment integrated system tests/EMC/RFI. After successful completion of the checkout of each individual experiment installed on the pallet/igloo, the experiments will undergo an integrated system test. This test is designed to verify each subsystem compatibility with all systems and experiment hardware. The data obtained from this phase of the test program will serve as a baseline for all future testing or troubleshooting of the specific payload configuration.

After review of the integrated test data and verification that no anomalies were detected, an electromagnetic compatibility (EMC) test will be performed to demonstrate that the experiments/pallet/igloo operated within margin requirements. The EMC tests will be conducted to ensure that no interference will exist in a normal mission timeline. Simultaneously, an abbreviated mission simulation including deployment and operation of the individual experiments will be conducted. The Orbiter/pallet/igloo EMC testing will be accomplished as a part of the Orbiter cargo integration (see Block 10.0) at the launch site.

Experiment integration tests will verify the deployment/operation of booms, antennas, solar arrays, etc., including those that may require special 1-g support structure for their deployment. Once these systems have been verified, however, subsequent operations at other sites will not be attempted unless there is evidence that their functional behavior has changed. The experiment integration tests will end when the test conductor coordinating the tests has verified that all procedural requirements have been met.

Mission simulation and crew training. Concurrent with the experiment integrated system test, a simulated mission is planned. It will use an abbreviated mission flight plan, flight hardware, and the mission flight plan to augment the flight crew training.

An abbreviated simulated mission will be performed by the actual crew with additional support provided when required. This activity is intended to verify the timeline sequencing and the feasibility of the crew to perform the prescribed operations. The simulation will serve as a bench-mark for future simulation training and actual flight operations.

Data review. Following completion of the experiment integration test, the pallet/igloo are powered down. The GSE remains connected, however, until a data review has been conducted and retest requirements (if any) have been established.

Data to be reviewed includes the following.

ACTIVITY DATA SHEET

2.0 ACTIVITY DESCRIPTION (CONT)

Flow Number: 4.0

- On-board recorded data - tapes, film, printer output, CCTV
- GSE data - strip charts, pen records, etc.
- Ground base data printouts
- Test documentation - discrepancy records (DR's), test conductor reports

All test anaomalies documented elsewhere, such as discrepancy reports and test conductor reports, will be reviewed to assist in determining the retest requirements. Discrepancies will be evaluated, fixes outlined, and retest requirements established. Satisfactory completion of retest requirements is necessary prior to NASA acceptance review of the experiment integration. Subsequent to completion of the retest effort, the pallet and igloo are powered down. The GSE remains connected, however, until completion of the final NASA acceptance review.

NASA acceptance review. After completion of the experiment integration retest, an acceptance review will be held to formally approve all data and documentation gathered to this point, and to approve the final disposition of rework. The review of all data generated during the integration is necessary to provide confidence that the pallet and igloos are ready to be integrated -nto the Orbiter vehicle. Costly schedule delays may be avoided if the readiness of the pallet to continue launch preparations is assessed at this time. The participants of this review would consist of both integration center (IC) or user and NASA personnel, including the principal investigators (PI's) and flight crews.

PALLET ONLY BLOCK 5.0 GSE DISCONNECT

*******1*******2*******3 WORKING DAYS

**** DISCONNECT P/IGL SIM, ORBITER SIM & AUX GSE FROM P/IGLOO
**** CLOSEOUT & SECURE PALLET/IGLOO PANELS COVERS & ACCESS PANELS
******** REMOVE EXPERIMENT SUPPORT EQUIPMENT FROM PSS SIMULATOR
******** PREPARE PSS MOUNTED HARDWARE FOR SHIPMENT TO LS (BAG/PACK/CRATE)

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ACTIVITY DATA SHEET

1.0 ACTIVITY IDENTIFICATION

Functional Flow Number: 5.0 Applicable Concepts: All

Title: GSE Disconnect

Principal Elements: Pallet/Igloo, Orbiter Simulator Set, Support System Igloo Simulator, Auxiliary GSE

2.0 ACTIVITY DESCRIPTION

After completion of the experiment checkout and integration activity (Block 4.0), all GSE utilized will be powered down and disconnected from the pallet. Experiment monitoring equipment (displays, controls, caution and warning devices, keyboard, etc.) and support equipment that are mounted in the Orbiter PSS are disconnected and removed from the PSS simulator. This equipment will be prepared for shipment, packaged, and sent to the launch site. Both simulators (Orbiter simulator set and the support system igloo simulator) are disconnected and transferred to the GSE maintenance area for refurbishment/reconfiguration and eventual revalidation.

After the simulator and auxiliary GSE have been removed from the integration area, the pallet and igloo coolant loops are deserviced and non-hazardous supplies are loaded. The final task is the cleanup of the integration area and the preparation of the PSS-mounted equipment for shipment to the launch site. The individual tasks that are completed are as follows.

Disconnect Orbiter simulator set and support system igloo simulator (including auxiliary GSE) from the pallet/experiment igloo. Following successful completion of the functional checkout of the integrated pallet/igloo, all connections at the Orbiter simulator set/pallet interface and at the support system igloo simulator/experiment igloo interface must be disconnected and secured. This is done after all pallet/igloo switches and controls are neutralized.

Coolant fluid is not drained from the pallet/igloo lines. Self-sealing zero-leak quick-disconnects prevent leakage and spillage. Cable connectors are capped and umbilical plugs secured.

The Orbiter avionics simulator equipment control and display console, power and coolant stub-ups are powered down and secured. All auxiliary equipment used for checkout of the individual experiments (reference standard samples, light sources, instruments, etc.) are disconnected, packaged, and returned to the owner or central supply.

ACTIVITY DATA SHEET Sheet 2 of 2

2.0 ACTIVITY DESCRIPTION (CONT) Flow Number: 5.0

Load non-hazardous supplies. After the coolant loops have been "deserviced" all non-hazardous supplies and equipment will be loaded. The non-hazardous supplies are those that neither will be affected by shipment or storage for any significant amount of time and, by their nature, do not represent a hazard.

Close out and secure pallet/igloo panels, covers and access doors. These activities will close out the pallet/igloo and are the final steps before preparing them for shipment to the launch site.

Remove experiment support equipment from PSS simulator. This activity involves the removal of the flight hardware experiments and their support equipment from the simulator set, and its preparation for shipment to the launch site. Experiment monitoring equipment (displays, controls, caution and warning system, keyboards, etc.) and auxiliary equipment are dismantled from the PSS simulator set and refurbished if necessary. (Pens are cleaned, ribbons changed, tapes removed, film replaced, etc.) Each unit of experiment flight hardware and support/auxiliary equipment is then bagged and crated for shipment.

The Orbiter simulator set and the support system igloo simulation equipment, including auxiliary GSE, are then transported to the maintenance area for refurbishment, reconfiguration and revalidation for the next payload test and operations.

PALLET ONLY BLOCK 6.0 PALLET/IGLOO SHIPMENT

```
*******1*******2*******3*******4  WORKING DAYS

**  PREPARE PALLET/EXPERIMENTS/IGLOO FOR SHIPMENT TO LAUNCH SITE
 *****  LOAD P/IGL IN SHIPPING CONTAINER, SECURE & REMOVE LIFTING DEVICES
     **  INSTALL SHIP CNTR COVER, SECURE & REMOVE LIFTING DEVICES
       ***  MOVE PALLET/IGLOO & PSS EQUIP TO AIR CARRIER LOADING SITE
          **  LOAD SHIPPING CONTAINER & PSS EQUIP ABCARD AIR CARRIER
            *  SHIP PALLET/IGLOO/PSS EQUIPMENT
            ****************  PALLET/IGLOO/PSS EQUIP ENROUTE TO LAUNCH SITE
                           *  PALLET/IGLOO/PSS EQUIPMENT ARRIVAL AT LS
```


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ACTIVITY DATA SHEET

1.0 ACTIVITY IDENTIFICATION

Functional Flow Number: 6.0 Applicable Concepts: All

Title: Pallet/Igloo Shipment

Principal Elements: Pallet, Igloo, PSS Experiment Equipment

2.0 ACTIVITY DESCRIPTION

Prior to shipment of the pallet and igloos to the launch site, the following tasks have been completed.

- The pallet/igloo have been refurbished, reconfigured and checked out.
- The experiment complement for this mission has been installed, aligned, and functionally checked out.
- Experiment integration has been completed.
- The Orbiter simulator set, support system igloo simulator and all supporting GSE have been disconnected from the pallet and experiment igloos.
- The pallet and igloo coolant loops have been deserviced.

The pallet/igloo and experiments are now ready for preparation and shipment to the launch site where they will be integrated with the Orbiter. The activities required to get ready for this shipment are as follows.

Repaint pallet/igloo exterior surface and conduct emissivity checks. To reduce the heat rejection demands upon the coolant system during orbital operations, it is necessary to coat the exterior surfaces of the pallet and igloos with thermal paint to obtain the proper balance of solar energy absorbtion (α) to emission (ε) as measured by the ratio of the parameters (α/ε). The steps required to accomplish this task are as follows.

- Verify that all panels/covers for the pallet and experiments are installed.
- Close/protect all penetration points such as vents, open lines, connectors, etc.
- Cover/protect all sensors and equipment

ACTIVITY DATA SHEET Sheet 2 of 2

2.0 ACTIVITY DESCRIPTION (CONT) Flow Number: 6.0

- Repaint/retouch pallet/igloo surfaces with thermal paint.
- Conduct emissivity checks of painted surfaces and verify required thermal characteristics (α/ε).

Connect listing devices and load pallet/igloo onto transporters. As in the previous activity, one of the initial parts of this task will be a verification that the lifting devices have current proof-load credentials. This operation is necessary to ensure that any overhead cranes, slings, or hoists used to lift the pallet have been accurately rated and are fully capable of handling the pallet.

The next operation will be to connect the sling/hoist to the pallet hydraset and traveling overhead crane. Once this connection has been completed, the pallet will be loaded onto the shipping pallet and then the transporter. After loading, it will be tied down to avoid damage during movement.

Installation of shipping cover and portable pressurization unit. The final operation on the pallet, prior to moving it, will be to install the shipping covers and portable pressurization unit. This activity is accomplished utilizing the sling/hoist and the traveling overhead crane. The cover will be lifted over the pallet and lowered down, secured and sealed to the shipping pallet for shipment to the launch site.

The shipping container/transporter should be instrumented (temperature, pressure, shock, and vibration), and these measurements recorded on a trip log. At some time in this activity, prior to installing the pallet shipping covers, this instrumentation system should be turned on and verified.

The attached portable pressurization unit maintains the environment of the volume enclosed by the shipping cover, purged and pressurized with dry nitrogen (GN_2) or some suitable inert gas, to protect the experiments, support equipment and pallet/canister from contamination. The portable unit will maintain a positive pressure during the shipment of the pallet to the launch site. Prior to leaving the integrator's facility, a leak check will be performed to verify the unit's ability to maintain the induced environment during transit.

Move pallet to point of embarkation and load aboard carrier. The pallet, on its shipping pallet, is placed on its transporter for the move to the air carrier loading site. The pallet-only configuration can be transported to the launch site by several air modes (either Boeing 747 or by Guppy). For planning purposes, an estimate of two days travel time will be used for the transporting of the pallet/igloo to the launch site.

The experiment support equipment to be installed in the Orbiter/PSS is also shipped to the launch site along with the pallet.

PALLET ONLY - BLOCK 7.C PALLET/IGLOO & PSS EQUIP ARRIVAL AND R/I

```
*******1*******2*******3  WORKING DAYS

*****  P/IGL OFF LOADED - TRANSPORTED TO MSOB
     ***  REMOVE SHIPPING CONTAINER COVER
       *****  REMOVE P/IGL FROM CONTAINER - PLACE IN FIXTURE - REMOVE LIFTING DEVICE
            ****  REMOVE P/IGL PANELS, COVERS & ACCESS DOORS - CONDUCT R/I
********  OFF LOAD PSS EQUIP - TRANSPORT TO MSOB
        ********  CONDUCT PSS EQUIP R/I
                ***  POST R/I SECURE
```


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ACTIVITY DATA SHEET

1.0 ACTIVITY IDENTIFICATION

Functional Flow Number: 7.0 Applicable Concepts: All

Title: Pallet/Igloo and PSS Equipment Arrival and Receiving/Inspection

Principal Elements: Pallet/Igloo and PSS Equipment

2.0 ACTIVITY DESCRIPTION

Upon its arrival at the launch site, the pallet will be off-loaded and transported to the MSOB. Prior to entering the MSOB, the transporter is cleaned externally to remove contaminants picked up during transit. This is necessary to enhance maintaining the clean room environment within the facility. At the MSOB facility the shipping cover and portable pressurization unit are removed. The pallet/canister are then lifted off the transporter and installed in the Orbiter cargo bay simulator (workstand or fixture) that is designed to simulate the cargo bay both dimensionally and functionally.

This fixture will verify the volume or envelope clearances and pallet attach points, as well as fluid and electrical connections which will be located in the same relationship to the pallet as in the actual Orbiter. If it is necessary (or desired), facility power, fluid stub-ups and GSE connections for Orbiter simulation equipment could be made part of the fixture. The lifting devices are removed and the pallet/Orbiter mechanical attach points are checked for proper connection and seating. Inspection panels and/or protective covers are removed and the pallet/canister will undergo receiving inspection (R/I).

Concurrent with these tasks, the equipment to be mounted/installed in the Orbiter or at the PSS will be off-loaded, transported to the MSOB, uncrated/unpacked, and processed through a similar R/I.

PALLET ONLY BLOCK 8.0 MATE PALLET & IGLOO

```
*******1*******2*******3  WORKING DAYS

****  MOVE PALLET TO INTEGRATION AREA (MSOB)
    **  VERIFY MATING SURFACE READINESS
      ******  INSPECT/VERIFY ELEC/MECH INTERFACES
            **  ALIGN IGLOO AND PALLET
              ***  MATE PALLET & IGLOO
                 *  VERIFY ELECTRICAL BONDING (GND) AT PALLET/IGLOO I/F'S
                  ****  CONNECT ELEC/MECH INTERFACES
```


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ACTIVITY DATA SHEET

1.0 ACTIVITY IDENTIFICATION

Functional Flow Number: 8.0 Applicable Concepts: All

Title: Mate Pallet and Support System Igloo

Principal Elements: Pallet/Experiment Igloos, Support System Igloo

2.0 ACTIVITY DESCRIPTION

The pallet, installed in a work stand in the MSOB, has previously been mated with experiment igloos. This activity covers the mating and installation of the final igloo. The support system igloo has been refurbished and maintained at the launch site and will be utilized as a flight article.

The first step in this process is an inspection of the mating surfaces of the support system igloo and the pallet. Verification of mating surfaces readiness is required prior to a detailed inspection of the electrical and mechanical interfaces. The igloo installation and mating will require auxiliary GSE such as cranes, hoists, etc., to handle the support system igloo. Alignment devices such as theodolites, autocollimators bench-marks, mirrors, levels and targets will be used to verify the mechanical alignment. Prior to the physical mating it will be necessary to perform a continuity check of the wiring connects at the pallet/support system igloo interface bracket. This check will include complete end-to-end checks of cell experiment igloo/support system igloo wire harnesses, experiment hardware connector pin assignments, and pallet/igloos/Orbiter wiring interfaces.

The wiring checks are verified by tracing the wire list, pin-to-pin. Note that end-to-end does <u>not</u> imply disconnecting the experiment igloo equipment cables that were previously verified during Block 3.0 (experiment installation), and 4.0 (experiment checkout and integration). The mating of the pallet and support system igloo will require the connection of all utilities that go across the pallet/support system igloo interface (cabling, plumbing, etc.). After mechanical mate and fasteners are torqued, the pallet and support system igloo are ready for verification of electrical and fluid connections. The final steps are wiring continuity checks and electrical bonding (ground), followed by a leak check of the fluid lines and connections.

PALLET ONLY BLOCK 9.0 SPACELAB INTEGRATION (NON-HABITABLE)

```
***1***2***3***4***5***6***7***8***9**10**11**12    WORKING DAYS

****  CONNECT GSE (SERVICE UNITS, ORB I/F SIM, & SUPPORT GSE
    **  SERVICE & VERIFY COOLANT FLOW THROUGH GSE FLD LINES & COLD PLATES
      *  PERFORM BUS ISOLATION TESTS
       *  CONDUCT PRE-POWER SW LIST VERIFICATION TO VERIFY SW & CONTROL SETTINGS
        *  POWER UP ELECTRICAL & FLUID LINES
        *  CONDUCT POWER DISTRIBUTION CHECKS
         *  VERIFY CAUTION/WARNING SYSTEM OPERATIONS (SENSORS & DISPLAYS)
         *  POWER UP SUPPORT SYSTEMS IGLOO IMS
         *  CONDUCT COMPUTER SELF CHECKS
          **  VERIFY IMS COMMAND/CONTROL
            *  C/O IGLOO IMS EQUIP, RECORDERS, SIGNAL CONDITIONERS, ETC
            *  C/O AUXILIARY EQUIP (CTTV, INTERCOM, LIGHTING, ETC)
            *  CHECK SIG DISTR VIA IGLOO/ORBITER UMBILICAL
             *  VERIFY GROUND DATA BASE COMPATIBILITY VIA THE GDB UMBILICAL
             ****  CONDUCT FUNCT C/O OF SUPPORT SYS IGL/EXPMT EQUIP I/F'S
                 *  POWER DOWN P/IGL & SUPPORT EQUIPMENT
                 *****  DATA REVIEW
                     *****  DISCONNECT GSE
                     *****  LOAD NON-HAZARDOUS SUPPLIES & CREW EQUIPMENT
                        **  CLOSEOUT P/IGL PANELS, HATCHES & ACCESS PANELS
                         ***  RETOUCH P/IGL EXTERIOR SURFACES WITH THERMAL PAINT
                            ***  CONDUCT EMISSIVITY TESTS
                              **  PREP IGLOO FOR PRESSURE DECAY LEAK CHECK
                                ****  CONDUCT IGLOO LEAK CK (24HR DECAY-  16HR ON 2ND &
                                      3RD SHIFTS)
                                    *  DEPRESSURIZE IGLOO & REMOVE GSE
                                     ****  CONDUCT WEIGHT & BALANCE TEST
```


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ACTIVITY DATA SHEET

1.0 ACTIVITY IDENTIFICATION

Functional Flow Number: 9.0 Applicable Concepts: All

Title: Spacelab Integration (Non-Habitable)

Principal Elements: Pallet/Igloos, Orbiter Interface Simulator

2.0 ACTIVITY DESCRIPTION

Following assembly of the Spacelab elements into the final flight configuration (Block 8.0) and the successful completion of experiment checkout and integration (Block 4.0), the Spacelab (non-habitable) integration (Level II) tests will be performed at the MSOB. The mated flight configuration of the pallet/experiment igloos and the support system igloo will be referenced in subsequent functional flow blocks as the "Spacelab (Non-Habitable)." When the final flight configuration pallet-only components are demated, they will again be referenced as "pallet, experiment igloo or support system igloo." The tests will include the following tasks.

GSE installation and checkout. This subtask is directed toward the installation and checkout of the fluid servicing units, Orbiter interface simulator and other support equipment. Servicing of the coolant loops with Freon and water, and gas systems are the initial steps of this subtask. Coolant and conditioned air flow rates and pressures will be monitored to assure capability to maintain Spacelab equipment temperatures in tolerance.

The Orbiter interface simulator will be checked to verify that its inputs to the Spacelab are representative of the actual Orbiter. The specific items to be evaluated are:

- Fuel cell/power distribution simulation
- Orbiter signal simulation
- Orbiter payload specialist station (PSS) equipment
- Umbilical interfaces
- Data management systems
- Computer and peripheral equipment
- Operator console

Verification of the functional performance of all GSE to be utilized during test is necessary prior to start of actual Spacelab integration.

Prepower checks and Spacelab (non-habitable) functional checkout. Spacelab functional checkout of the pallet and igloos will begin after the GSE has

ACTIVITY DATA SHEET Sheet 2 of 3

2.0 ACTIVITY DESCRIPTION (CONT) Flow Number: 9.0

been certified as on-line and ready to support testing. This block consists of the following tasks.

- Perform bus isolation tests to verify that all loads have been removed from Spacelab bus, and determine the impact of sequential loading during integrated testing (i.e., current versus load tests).
- Conduct a prepower-up switch list check to ensure that there will be no spurious or unknown loads applied to the Spacelab bus at the start of testing and to verify control/switch positions are proper prior to the application of Spacelab power.
- Upon completion of bus isolation and switch list verification, power-up of Spacelab electrical and fluid systems will occur. Bus voltages/current and coolant flow will be carefully monitored during power-up.
- Power distribution checks will be conducted to verify continuity and operation of each circuit, including verification that all indicators are consistent with the operation performed.
- Spacelab caution/warning system operation will be verified prior to start of system testing C/W. Push-to-test circuits, re-sets, and talkbacks will be checked. All C/W sensors and displays must be working properly before system testing can begin.
- The Spacelab IMS will be the first to be activated. Since the computer is fundamental to the command and control of other Spacelab systems, it is necessary to establish its operability by utilizing a compueter self-check routine. When proper computer operation has been verified, command and control tests will be conducted to establish operational states of that portion of the information management system (IMS). These tests will utilize special computer routines that verify command and response functions prior to exercising actual control by the IMS. These tests are procedural verification checks. Computer peripheral equipment, line printers, recorders, etc., are also evaluated during these computer tests.
- The final activity of this subtask is the Spacelab functional checkout of support systems and experiment equipment interfaces. Control and command of Spacelab functions will be accomplished utilizing the IMS system. Manual emergency backup modes that utilize the crew will also be evaluated where they occur. Experiment equipment interfaces are the only factors to be evaluated

ACTIVITY DATA SHEET

2.0 ACTIVITY DESCRIPTION (CONT)

Flow Number: 9.0

during Spacelab integration; i.e., experiment operations and functions were assessed during the experiment integration tests and will not be repeated. Following completion of Spacelab functional tests, the Spacelab and GSE are powered down for a review of accumulated data.

Data review. A data review of Spacelab integration test data will be accomplished with participation by NASA and contractor personnel. All recorded data from tapes, charts, annotated procedures, etc., will be examined prior to approval for test teardown. A formal review of one day, as shown in the test flows, assumes that some reduction and tabulation of data have been occurring throughout the progress of the Spacelab integration tests.

Disconnect GSE and load non-hazardous supplies. Following approval of the Spacelab integration test (Level II) data results, the Orbiter interface simulator set and the auxiliary GSE utilized will be disconnected from the pallet/igloos. Non-hazardous supplies needed by the experiments or the support system igloos will be loaded at this time. Radioactive sources, pyrotechnic devices, high-pressure gases or time-critical experiments (i.e., samples) will be loaded at the launch pad. After loading is completed, access panels and cover plates will be installed the the Spacelab closed out.

Emissivity checks and Spacelab leak-checks. Following closeout of the Spacelab, the surfaces exposed to solar radiation in space may require application or touchup with thermal paint. Emissivity tests are then conducted to verify specification requirements of the ratio of solar absorption to emissivity (α / ε).

In parallel with the emissivity tests, preparations for Spacelab pressure decay leak check will occur. This latter activity includes connecting pressurized igloos or other containers to a gaseous fluid distribution system for pressurization with an inert gas such as nitrogen (N_2). These containers will be pressurized and leak checks performed. After satisfactory completion of leak-rate checks, pallet pressure containers will be depressurized and the test setup disconnected.

Spacelab weight and balance. Weight and balance checks of the pallet and igloo in as near flight configuration as possible will follow the leak checks. Load cells are to be used to determine gross weight and center-of-gravity values for the Spacelab. Items not loaded because of other considerations will be accounted for analytically. Verification that the center of gravity and gross weight are within Orbiter tolerances is necessary before the payload can be loaded aboard the Orbiter.

PALLET ONLY BLOCK 10.0 ORBITER CARGO INTEGRATION

```
*******1*******2*******3*******4*******5  WORKING DAYS

************************  8 HOUR WORK DAY
                                          WORKING DAYS

**  CONNECT LIFTING DEVICES TO PALLET/IGLOO
 ***  LOAD P/IGL IN SHIPPING CONTAINER, SECURE & REMOVE LIFTING DEVICES
  **  INSTALL SHIPING CONTAINER COVER & SECURE
    **  MOVE P/IGL & PSS/ORBITER EQUIPMENT TO OPF
      *****  OFF LOAD P/IGL & PSS/ORBITER EQUIP AT OPF & REMOVE LIFTING DEVICES
     *  VERIFY ORB READINESS TO INSTALL PSS/ORB EXPMT SUPPORT EQUIP
     ****************  INSTALL PAYLOAD RELATED EQUIP IN ORB/PSS STATIONS
           **  INSPECT P/IGL ELECT/MECH INTERFACES
             *****  SERVICE P/IGLOO WITH NON-HAZ FLUIDS, LOW PRESSURE GAS & SUPPLIES
                 ****  INSTALL FLIGHT BATTERIES & CHARGERS
                    *  VERIFY ORBITER READINESS TO ACCEPT PALLET/IGLOO
                    **  CONNECT LIFTING DEVICES TO PALLET/IGLOO
                      ***********  16 HOUR WORK DAY
                      **  LOAD PALLET/IGLOO IN ORBITER - VERIFY PLUGS OUT CONTINUITY
                        *  VERIFY ORB/P/IGL INTERFACES
                         ******  CONDUCT AVIONICS OPERATIONS TEST WITH ORB/P/IGL SYSTEMS
                               *  EMC/RFI TEST WITH ORB/P/IGL SYSTEMS OPERATING
                                *  INSTALL/CONNECT ORDNANCE NOT ACCESSIBLE AT PAD
                               **  DATA REVIEW - FINAL P/IGL FLIGHT APPROVAL
```


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ACTIVITY DATA SHEET

1.0 ACTIVITY IDENTIFICATION

Functional Flow Number: 10.0 Applicable Concepts: All

Title: Orbiter Cargo Integration

Principal Elements: Pallet, Experiment Igloos, Support System Igloo, and Orbiter

2.0 ACTIVITY DESCRIPTION

Orbiter cargo integration (Level I) is the final test and operations checkout of the Spacelab payload prior to loading it into the Orbiter cargo bay. It also involves the checkout and integration of the experiment equipment that is mounted and operated in the PSS.

Following successful completion of the Spacelab integrated test (Block 9.0) and the acceptance of the results during the data review, the pallet/igloo will be loaded aboard their shipping container and transported from the simulator fixture in the MSOB and moved to the Orbiter Processing Facility (OPF). The following steps will be performed during the movement of the pallet.

- Connect lifting devices to pallet/igloo.
- Protective panels and covers are reinstalled on the pallet or igloo.
- Install shipping container cover and secure.
- Remove Orbiter/PSS equipment from simulator and prepare for transfer to OPF.
- Lifting devices (slings and hoists) are attached to the pallet tie points and mechanical connections to the Orbiter interface simulator are removed.
- Final connection of crane/hoist and load pallet/igloo on transporter. Remove lifting devices.
- Service transporter to preclude contamination during move.
- Transport pallet to OPF.
- Clean external surfaces of Spacelab and PSS equipment prior to entry to OPF.
- Remove soft cover set.
- Attach lifting devices and transfer Spacelab from transporter to dolly.

ACTIVITY DATA SHEET

2.0 ACTIVITY DESCRIPTION (CONT)

Flow Number: 10.0

- Remove lifting devices and secure GSE for storage.

The final step of the activities will be a verification of Orbiter readiness for the installation of the PSS experiment equipment in the crew compartment. Following the verification that the Orbiter is available, the various items of experiment monitoring instruments (controls and displays) and the support equipment (caution and warning, computers, RAU's, etc.) are installed in the Orbiter and PSS. These tasks are performed concurrently with the following operations:

- Inspect pallet/igloo electrical and mechanical interface connections (includes wire list check, Orbiter/igloo umbilical check, etc.).
- Service the Spacelab with non-hazardous fluids, low-pressure gases and other non-hazardous consumables and supplies such as film for cameras.
- Install flight batteries and chargers.
- Conduct Orbiter/pallet/igloo compatibility review to verify Orbiter readiness to accept the Spacelab.
- Connect the lifting devices and load the pallet into the Orbiter payload bay.
- Remove the lifting devices; verify plugs-out electrical continuity; connect the umbilical cables and fluid lines; install mechanical latches and retention devices.
- With the completion of installation of experiment equipment in PSS, and the Orbiter/pallet/igloo interface verification, the Orbiter avionics test (OAT) will be conducted. This avionics operations test performed in conjunction with the Orbiter avionics checkout, verifies that the Orbiter performance monitoring system (PMS), computer, telemetry, caution and warning (C&W) and other avionics functions are compatible with the IMS.

This activity is considered to be an integral part of the Orbiter launch preparation operations and does not add to the Spacelab test and operations time or cost. The test is designed to verify that the following specific operations occur:

- The caution/warning displaysare driven by the Orbiter C/W crivers.

ACTIVITY DATA SHEET

2.0 ACTIVITY DESCRIPTION (CONT)

Flow Number: 10.0

- The GMT, MET, navigation and orientation data are transferred to the pallet IMS; the pallet/subsystems performance monitoring data are processed by the Orbiter pre computer.
- The Orbiter payload data interleavers insert the data into the Orbiter PCM unit.
- The Orbiter command decoder transmits the commands to the pallet IMS.
- The audio/intercom system is operable.
- The pallet IMS can transfer wide-band data to the Orbiter transmitter.

Immediately after successful completion of the OAT, there will be an EMC/RFI test.

Electromagnetic compatibility and non-RF interference between the Orbiter and pallet subsystems are to be demonstrated by concurrent operation of the Orbiter and pallet/subsystems. Note that almost all experiment sensors and electronics are neither susceptible to, nor emitters of, radiation in the Orbiter communications frequency bands; therefore, the sensors need not be activated. Potential noise generators (servo motors, solenoids, and pmups) have been suppressed by design requirements and demonstrated to be "clean" prior to the experiment (Level IV) integration. EMC is to be demonstrated by monitoring the Orbiter power distribution loads, voltages, etc. (via the Mission Specialist Station), plus the Orbiter avionics as the pallet/subsystems are exercised. Detected interference will be located and corrected, using EMI/RFI instrumentation.

The final two steps of this activity are the installation/connection of ordnance devices in locations that will not be accessible at the pad and the data review of the Orbiter cargo integration test results. Final data review of the Orbiter/pallet integration results will be performed by user, crew (astronaut-scientist, PI), PI, safety and mission control representatives. The review approval is necessary to the final flight plan approval.

With final approval of the pallet readiness, the Spacelab systems are secured, GSE removed and all access panels replaced. This operation concludes the pallet/igloo activity in the OPF. Following cargo bay closeout, the Orbiter is moved into the transfer aisle of the VAB, vertically erected and placed in one of the high bays. No further access to the pallet is anticipated until launch countdown operations at the pad.

PALLET ONLY BLOCK 11.0 LAUNCH OPERATIONS

```
*******1*******2*******3*******4*******5  WORKING DAYS

**********************************  16 HOUR WORK DAY (ORBITER TIME LINE)
                    *  CONDUCT FINAL PAYLOAD PRE-LAUNCH FUNCT TEST (PARR W/ORB LRV TEST)
                     *  FINAL DATA REVIEW
                      *  LOAD TIME CRITICAL CONSUMABLES
                       ***  LOAD HAZARDOUS CONSUMABLES
                          **  DISCONNECT FLUID DISTRIBUTION SYSTEM
                           *  CLOSEOUT P/IGL/PSS SYSTEMS FOR LAUNCH
                              *  LAUNCH
```


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ACTIVITY DATA SHEET

1.0 ACTIVITY IDENTIFICATION

Functional Flow Number: 11.0 Applicable Concepts: All

Title: Launch Operations

Principal Elements: Pallet, Igloos, Orbiter

2.0 ACTIVITY DESCRIPTION

The launch operations (Block 11.0) steps cover the pallet activities at the pad from the conducting of the final payload prelaunch functional test, and run in parallel with the Orbiter launch readiness verification (LRV) test, through the closeout of the pallet/igloo/PSS systems for launch. The completed steps are as follows.

Final payload prelaunch functional checkout. This checkout is required to verify the functional operability of the pallet/igloo and experiment systems. It is not designed to obtain quantitative performance data for future analysis, but rather to ensure that the equipment continues to function following the erection of the Orbiter and the subsequent move to the launch pad.

The payload systems, including experiment equipment, will be operated to verify system operability; to determine operational anomalies; and to effect repairs or document out-of-limit tolerances and their ultimate disposition (i.e., go, no-go, change, modify, or use as-is). In general, the checkout will not require input stimulus to the experiment sensors which, although powered, will be monitoring static or ambient conditions. Mechanical devices such as antennas/booms will not be deployed. This final payload prelaunch functional test is to be performed in parallel with the Orbiter launch readiness verification.

Following the functional test, a data review will be conducted with principal investigator (PI) participation.

Final data review. A review of the data obtained from the final payload prelaunch functional test will be conducted at this time. The review will be performed by the user, flight crew, PI's, and safety/mission control representatives.

Any malfunctions, out-of-tolerance conditions, or discrepancies detected will be resolved at this time. The determination will also be made at

ACTIVITY DATA SHEET

2.0 ACTIVITY DESCRIPTION (CONT)

Flow Number: 11.0

this time whether to fly as-is, replace, or repair. Any revisions to the final flight plan will also be accomplished during this data review.

Load time-critical consumables. After the data review, all time-critical consumables such as film, recording tapes, etc., will be loaded. Because of the critical relationship of the operations to the time of the final launch countdown, at this time such operations should be minimized or eliminated wherever possible.

Prepare for and load hazardous materials. The next task involves the loading of hazardous materials and the final closeout of the pallet/igloo prior to launch.

Certain safety-related items that constitute hazards to personnel or equipment must be loaded during countdown. Some of the items falling into this category include cryogens, hypergolics, high-pressure gases, radiation sources, etc. These materials should be the final items loads since optimum pad operations would be to deny access to all but the flight crew after such loading. Preparation for loading these hazardous consumables include the following steps.

- Connect the fluid distribution systems for hazardous consumables (cryogens, hypergolics, and high-pressure gases) to the access ports on the Orbiter.

- Connect the fluid distribution system to the sources: (1) Orbiter propellant supplies. or (2) portable supply tanks such as a portable dewar.
  [This system (if required) would be a special GSE item.]

- Inspect all connections for correct attachment, connection seating, and valve settings before beginning the transfer.

The final task of this activity is the transfer of the hazardous consumables from the source to the pallet/igloo and experiments.

Disconnect fluid distribution system. After transfer of hazardous consumables is complete, the connections at the pallet/igloo access ports and the supplies are disconnected and sealing of the connection points are verified.

This completes the pallet/igloo experiment closeout activities prior to launch.

PALLET ONLY BLOCK 13.0 POST FLIGHT OPERATIONS

**********1**********2 WCRKING DAYS

********** 16 HOUR WORK DAY (ORBITER TIME LINE)
* ORBITER LANDING
********** ORBITER POST LANDING ACTIVITIES (REF)
**** REMOVE EXPERIMENT RELATED EQUIPMENT FROM ORBITER COMPARTMENT
**** CONNECT LIFTING DEVICES TO PALLET/IGLOO & REMOVE PALLET/IGLOO
******** BEGIN 8 HOUR WORK DAY/40 HOUR WORK WEEK
******** PREP & SHIP PSS/ORB MOUNTED EXPMT EQUIP TO USER/IC (NOT A SERIAL TASK)
** CONNECT LIFTING DEVICES - REMOVE SUPPORT SYS IGL

** LOAD P/IGL IN SHIPPING CONTAINER & SECURE
* INSTALL SHIP CNTR COVR & PORT PRESS UNIT - ACTIVATE

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ACTIVITY DATA SHEET

1.0 ACTIVITY IDENTIFICATION

Functional Flow Number: 13.0 Applicable Concepts: All

Title: Post-Flight Operations

Principal Elements: Pallet/Igloo/Orbiter [Spacelab (Non-Habitable)]

2.0 ACTIVITY DESCRIPTION

These activities are a part of the Orbiter safing activities and will be performed in parallel with the analogous Orbiter operations. Mobile cooling is attached, and the Orbiter is towed to the OPF within two hours of landing. After venting, purging, etc. (about 16 hours after landing), the cargo bay doors can be opened. Approximately 8 hours are allocated to disconnect and remove the payload (pallet). Orbiter/payload safing activities include the following.

- Post-flight operations commence with the Orbiter landing. After landing, the Orbiter will be towed to the safing area where it will be allowed to cool. Residual propellants will be drained and high-pressure gases vented. The Orbiter is then made safe in all areas.

- The same safing operations will be made on the pallet, with all hazardous propellants (if any) drained and high-pressure gases vented. Pallet batteries will also be removed at this time, if feasible.

The flight crew and scientist-astronauts egress at this time, and any time-critical experiments and data are off-loaded. Films, data samples and data tapes are removed and sent to the experiment ground data facility.

Concurrent with the off-loading of the pallet/igloo, the experiment equipment mounted in the PSS are removed. The PSS-mounted experiments and auxiliary equipment will be packaged at the launch site and sent directly to the user/PI for further disposition. Common payload support equipment such as meters, displays and controls or CRT's, etc., will be sent with the pallet and experiment igloos to their owner (either the integration center or user) for subsequent refurbishment and checkout. The containers/crates in which the packages are sent are the same ones that were used to transport this equipment to the launch site originally. Because this effort is post-mission, the time estimates will be somewhat shorter on the equipment-return phase.

ACTIVITY DATA SHEET

2.0 ACTIVITY DESCRIPTION (CONT)

Flow Number: 11.0

Upon completion of Orbiter safing, it is towed to the OPF where the Orbiter is jacked and leveled; work platforms are installed around the Orbiter, GSE connected, cargo bay doors opened, and the pallet is readied for removal from the cargo bay.

- The pallet will be disconnected at the pallet/Orbiter interface attach points along with the umbilical, fluid lines and electrical cables.
- Pallet/Orbiter retention devices will be released.
- Pallet lifting devices (slings/hoists) will be installed.
- The pallet is then removed from the bay and placed on its transporter. The pallet is tied down and the lifting devices are removed.

The support system igloo is then disconnected at its interface to the pallet and experiment igloos. The support system igloo is removed from the pallet and placed on its handling dolly.

The final task of this activity is the installation of the shipping container cover and tie-down, followed by installation and activation of the portable pressurization unit.

PALLET ONLY BLOCK 14.0 REFURBISH SUPPORT SYSTEM IGLOO

```
*******1*******2*******3*******4*******5*******6*******7********8  WORKING DAYS

****  MOVE SUPPORT SYSTEMS IGLOO TO REFURBISHMENT AREA
    ****  REMOVE SYS IGLOO ACCESS BULKHEAD & CONDUCT POST FLIGHT INSPECTION
        ********  DRAIN, FLUSH, DRY & CAP COOLANT SYSTEM - REPLACE/CLEAN FILTERS
              ****  VERIFY OPERABILITY OF FLUID SYSTEMS COMPONENTS
                  ****  INSPECT CABLES, CONNECTORS & FLD LINES - REPAIR ANY DAMAGE
                      ************************  REFURBISH & VERIFY OPERABILITY OF IMS
                                                COMPONENTS
                                              **  INSPECT S/S IGL/PALLET MATING
                                                  SURFACES FOR CORROSION/STRESS CRACKS
                                                **  CLEAN/POLISH MATE SURFACES, ALODINE
                                                    & REPAIR ANY DAMAGE
                                                  **  VACUUM CLEAN INTERIOR & EXTERIOR
                                                      S/S IGL SURFACES
                                                    **  PAINT/RETOUCH S/S IGL SURFACES
                                                        WITH THERMAL PAINT
                                                      ****  CONDUCT EMISSIVITY CKS &
                                                            VERIFY THERMAL
                                                            CHARACTERICTICS
```


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ACTIVITY DATA SHEET

1.0 ACTIVITY IDENTIFICATION

Functional Flow Number: 14.0 Applicable Concepts: All

Title: Refurbish Support System Igloo

Principal Elements: Support System Igloo

2.0 ACTIVITY DESCRIPTION

This activity describes the test and checkout requirements for the refurbishment of the support system (S/S) igloo subsystems. The approach utilized in the refurbishment of the S/S igloo will be a replacement of expendables or degraded parts with components that are either new, or have been through a maintenance cycle. These replacement components would have been checked out prior to installation. An example would be a TV camera. After 200 hours of operation, the vidicon image tube must be replaced. After replacement, the entire focusing, deflection, gray scale, etc., must be tuned. This is a bench operation; it is not appropriate to do this tuning in-place. It is more efficiently accomplished in an electronics lab. The entire camera would be removed and replaced after it is refurbished with a spare. The actual repair, test and certification of components and subassemblies would be accomplished in a lab. It is considered to be off-line and not a part of the service module test and checkout operation flow.

After each mission the S/S igloo subsystems will not be completely disassembled, checked, and then reassembled. Only those components that have failed on previous missions, or have reached the replacement stage because of the number of cycles they have performed or the total elapsed time they were used, or expendables that are replaced after each flight. Therefore, refurbishment and modification shall be on a remove-and-replace basis.

The S/S igloo checkout is accomplished in a "stand-alone" configuration--that is, separate from the effort related to the pallet and the experiment igloos. The S/S igloo subsystems are relatively standard for each mission; therefore, the components and procedures for demonstration of capabilities are also standard. Simulators were assumed to be used for subsystems checkout and represent pallet/support system igloo/experiment igloo interfaces. Removing the S/S igloo from the pallet/experiment igloo test and checkout should result in faster (more efficient) recycling.

After all subsystems have been refurbished, the S/S igloo information management system (IMS) will be system-utilized for checkout of other

ACTIVITY DATA SHEET

2.0 ACTIVITY DESCRIPTION (CONT)

Flow Number: 14.0

subsystems. The S/S igloo IMS performs this function for the entire pallet/experiment igloo during the mission, and should be able to perform the same function for these ground operations. It can be thought of as another terminal of the launch processing system; on the concept verification system; or any other ground simulation, test and recording system.

Refurbish and verify operability of IMS components. Since the S/S igloo IMS subsystem is used to verify the operability of the other subsystems, it will undergo the more extensive checks. The IMS checkout will include:

- Computer self-test. This is a standard program stored in the mass memory, complete with test problems, error checks and diagnostics. The computer, keyboard and displays, and tape recorder are needed.

- Instrumentation self-test. This is another standard program that exercises the data bus and RAU's by sequentially interrogating each one for a "status check." The status check is a built-in test function in the RAU.

- Command/control verification. The computer is loaded with the programs that interpret manual keyboard and hand-controller functions, and any special display format functions. The operator then commands (via his controls) selected operations which are simulated, and the results are displayed for his evaluation.

- Peripheral equipment verification. These are additional programs to exercise data recorders, printers, plotters, etc., that are mounted on the PSS. These are test signals--that is, simulated data that are enserted to verify the correct operation.

- Auxiliary equipment verification. These are manual (not computer) actions to verify the CCTV operation, the film equipment, etc., like a check list.

- Experiment displays/controls verification. The experiment-unique displays and controls are presumed to be hardwired to the DM/pallet-installed equipment; since this equipment is not yet present, the signals must be simulated by some form of GSE.

- Orbiter umbilical verification. Certain signals (caution/warning, voice, data) will cross the interface via an umblical; the Orbiter can be simulated by a test box (GSE). This is primarily a wiring check where the operator selects a wiring path, injects a stimulus and observes a response.

ACTIVITY DATA SHEET Sheet 3 of 4

2.0 ACTIVITY DESCRIPTION (CONT) Flow Number: 14.0

This should complete the IMS verification. It is now ready to be used to verify the remainder of the S/S igloo subsystems.

Support system igloo subsystems refurbishment. The activies begin with the removal of the S/S igloo from the pallet and its transfer to the refurbishment area. At the maintenance area, the access bulkhead for the igloo will be unbolted and removed to facilitate a post-flight inspection of the components in the igloo. After the inspection, the following steps will be completed.

- Thermal control system. Drain and flush igloo coolant system. Reservice and conduct flow performance checks. Examine all cabling connectors, fluid lines and connections for damage and/or wear; if any replacements or repairs are necessary, perform the required action. Drain and flush the coolant lines, coldplates and circulating pumps for the experiment equipment not removed. Service the coolant system with clean coolant and conduct flow checks. Verify (1) pump speed, (2) inlet and outlet pressures, and (3) use flow meter or GSE to measure line loss.

- Remove test circulation loops and cap coolant lines.

- Electrical power system. Following the refurbishment of the thermal control assemblies, the electrical power system will be examined and refurbished.

- Examine cable/wire harnesses from S/S igloo to experiment igloos.

- Examine and check out S/S igloo electrical assemblies: experiment inverters, emergency battery (remove), power control box, secondary power distribution assembly and subsystem inverter.

After the checks of the electrical power system, a functional check of the equipment will be performed to verify that it is operating properly and can adequately support another mission. The controls and displays that are utilized to monitor the S/S igloo electrical power subsystem are verified in an electronics lab.

- Examine/inspect support system igloo structure. The structure and mating surfaces of the S/S igloo will undergo the following operations:

ACTIVITY DATA SHEET

2.0 ACTIVITY DESCRIPTION (CONT)

Flow Number: 14.0

- Examine the mating surfaces of the S/S igloo, including attach bolts; inspect for corrosion and stress cracks.
- Clean and polish surface deteriorations; repair where required, and alodine the mating surfaces
- Examine igloo structure for stress/degradation; repair as required.
- After the igloo has had the subsystem components removed, the support brackets and both interior and exterior surfaces are vacuumed and cleaned.
- Paint and retouch the igloo surfaces with thermal paint.
- Conduct emissivity checks of the painted surfaces of the igloo and verify that it demonstrates the required thermal properties.

PALLET ONLY - BLOCK 15.0 PALLET/IGLOO SHIPMENT

```
*******1*******2*******3*******4*******5*******6  WORKING DAYS

**  MOVE P/IGL & PSS EQUIP TO POINT OF EMBARKATION
  **  LOAD P/IGL AND PSS EQUIP ABOARD CARRIER
    *  SHIP P/IGL AND PSS EQUIP FROM LAUNCH SITE
    ***************  P/IGL & PSS EQUIP ENROUTE FROM LAUNCH SITE
                  *  P/IGL ARRIVAL FROM LAUNCH SITE
                  *  PSS EXPMT RELATED EQUIP ARRIVAL FROM LAUNCH SITE (REF)
                  *****  OFF LOAD P/IGL & TRANSPORT TO EXPMT INTEGRATION AREA
                       ****  REMOVE SHIPPING COVER AND PRESSURIZATION UNIT
                           ***  CONNECT LIFTING DEVICES TO P/IGL - REMOVE TIE DOWNS
                              ****  REMOVE P/IGL & PLACE IN FIXTURE - REMOVE LIFTING
                                    DEVICES
                                 ****  REMOVE PANELS/COVERS - CONDUCT R/I
```


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ACTIVITY DATA SHEET

1.0 ACTIVITY IDENTIFICATION

Functional Flow Number: 15.0 Applicable Concepts: All

Title: Pallet/Igloo Shipment

Principal Elements: Pallet/Igloos

2.0 ACTIVITY DESCRIPTION

After completion of the post-flight operation (Block 13.0), the pallet and experiment igloos are prepared for and shipped back to the user (VIII) or the IC (VI and VII). The activities of this block are concerned with the actual movement of the previously prepared pallet, experiment igloos and PSS-mounted experiment equipment to the point of embarkation. This will be the landing site for the aircraft (Boeing 747 or Guppy) that is used to ship these containers to their refurbishment sites. The preparation/crating and handling of these packages and experiment equipment are discussed in Block 13.0.

The plans have included a two-day period for air shipment of the pallet/experiment igloos and the PSS equipment.

Upon arrival at the owner's facility, the pallet/igloo will be off-loaded from the air carrier and placed on transporter and moved to the experiment integration area. Once the equipment has been secured in position at the owner's site, the portable pressurization unit will be deactivated and removed. After removal of the shipping cover (pallet/igloo), and opening of shipping containers (PSS experiment equipment), all packages/equipment will undergo a receiving inspection to determine the condition and evaluate the potential of any in-process shipping damage.

The receiving inspection (R/I) on the pallet and igloo will be conducted after the lifting devices (slings and hoists) have been connected and the pallet is placed on a work dolly and all inspection plates/panels/covers have been removed. After completion of R/I, the pallet/igloo will be ready to have the experiments removed from the pallet and experiment igloos. These experiments, along with their associated equipment that was mounted in the Orbiter, will be returned to the PI for refurbishment and/or reuse on subsequent missions. This activity is not considered to be a primary part of the pallet test and operations flows. Experiment refurbishment is an off-line activity and does not impact the serial processing items.

PALLET ONLY BLOCK 16.0 REMOVE EXPERIMENTS/EQUIP FROM PALLET/IGLOO

*******1*******2*******3*******4*******5*******6 WORKING DAYS

************************ REMOVE EXPERIMENTS & SUPPORT EQUIPMENT FROM PALLET/IGLOO
**************** REMOVE EXPMT SYSTEM CABLING, LINES & BRACKETS FROM PALLET & IGLOO

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ACTIVITY DATA SHEET

1.0 ACTIVITY IDENTIFICATION

Functional Flow Number: 16.0 Applicable Concepts: All

Title: Remove Experiments and Equipment from Pallet/Igloo

Principal Elements: Pallet/Experiment Igloos

2.0 ACTIVITY DESCRIPTION

Block 16.0 has two principal activities:

- Removal of experiments and support equipment from the pallet and igloo.
- Removal of experiment system cabling, lines and brackets from pallet and igloo.

In Concepts VI and VII, this effort will be performed at the integration center (IC), with the experiments then being packaged and shipped to the user/PI. In Concept VIII, the entire T&O processing flow occurs at the user's facility; therefore, these removal activities will not be followed by an experiment shipment. Since there may be a very limited amount of reflying of experiments, the initial activity in the process of refurbishing the pallet/igloo will be the removal of the experiments and associated equipment from the pallet and igloo. These removed experiments will be packaged/crated and sent to the refurbishment area at the user's facility to be refurbished and stored, refurbished and returned to central supply, or returned to the affected PI.

This refurbishment of the experiments to be reflown is not included in this study. Those to be reflown on the next mission, however, must be reconfigured/refurbished, retested, and prepared for return to the experiment integration area within TBD days.

In addition to the experiment equipment that is removed from the pallet/igloo, there are cables and brackets that have to be removed and/or reconfigured prior to the installation of the next flight's complement of experiments.

Flow paths of the removed equipment will have to be capped. At the same time, these lines can be checked to verify that there is no fluid contamination.

ACTIVITY DATA SHEET

2.0 ACTIVITY DESCRIPTION (CONT)

Flow Number: 16.0

The extended digital data base (XDDB) equipments (RACU, BIU) will be removed and transferred to the maintenance bench for checkout and repair. They will be reinstalled with the new experiment complement. The next step will involve a check of the condition of the caution/warning indicators, vehicle instrumentation and signal conditioning, and circuit breaker operation. Replacements will be made as necessary.

PALLET ONLY BLOCK 17.0 EXPERIMENT SHIPMENT

```
*******1*******2*******3*******4  WORKING DAYS

***********  PREP EXPERIMENTS FOR SHIPMENT TO USER/PI FACILITY
          *  SHIP EXPERIMENTS TO USER/PI
          ********  EXPERIMENTS ENROUTE TO USER/PI FACILITY
                 *  EXPERIMENTS/EQUIP ARRIVAL AT USER/PI FACILITY
```


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ACTIVITY DATA SHEET

1.0 ACTIVITY IDENTIFICATION

Functional Flow Number: 17.0 **Applicable Concepts:** All

Title: Experiment Shipment

Principal Elements: Experiments and Auxiliary Equipment

2.0 ACTIVITY DESCRIPTION

This activity involves the preparation for and shipment of all the experiments, experiment support equipment, wire harnesses, brackets. etc., removed from both the pallet and igloo.

Each instrument and piece of equipment will be sealed in a weather-proof bag with desiccant and placed into its shipping container/crate. Each shipping container will be sealed and pressurized with an inert gas (GN_2) for environmental protection.

These items will then be delivered to an air freight site, loaded on-board a commercial carrier, and sent to the user's facility for future disposition. Special arrangements will be made for transporting equipment too large for air freight (on an individual basis).

For planning and scheduling purposes, an estimate of one day will be used for transporting the experiments and support equipment to the user's facility.

Those experiments/support equipment to be reflown on the next mission must be refurbished/reconfigured, retested and ready to be returned to the experiment integrator's facility within TBD days.

PALLET ONLY - BLOCK 18.0 REFURBISH/RECONFIGURE PALLET AND IGLOO

```
*******1*******2*******3*******4  WORKING DAYS

****  CRAIN/FLUSH P/IGL COOLANT LOOP - REPLACE/CLEAN FILTERS
    **  SERVICE COOLANT LOOPS - ESTAB CIRCULATION LOCPS - CONDUCT FLOW PERFOR CHECKS
      ***  PERFORM FUNCT CHECK OF PWR CONDITIONING EQUIP ON PALLET & IGLOO
         **  REMOVE TEST CIRCULATION LOOPS - CAP/BAG COOLANT LINES
         **  REMOVE BRACKETRY/STRUCTURAL ELEMENTS NOT REQUIRED ON SUBSEQUENT FLIGHTS
           **  REMOVE ATTACH BOLTS AT P/IGL I/F - MOVE DOLLIES APART MAINTAINING ALIGNMENT
             *  EXAMINE MATING SURFACES/ATTACH BOLTS FOR CORROSION/STRESS CRACKS
              **  CLEAN/POLISH SURFACE DETERIORATIONS - ALODINE SURFACES - REPAIR AS
                  REQUIRED
             ***  EXAMINE/INSPECT P/IGL STRUCTURE FOR STRESS/DEGRADATION - REPAIR AS
                  REQUIRED
                **  VACUUM/CLEAN P/IGL SURFACES
                  ***  PAINT/RETOUCH SURFACES WITH THERMAL PAINT
                     ***  CONDUCT EMISSIVITY CHECKS OF PAINTED SURFACES - VERIFY THERMAL
                          CHARACTERISTICS
```


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ACTIVITY DATA SHEET

1.0 ACTIVITY IDENTIFICATION

Functional Flow Number: 18.0 Applicable Concepts: All

Title: Refurbish/Reconfigure Pallet and Igloo

Principal Elements: Pallet, Experiment Igloos

2.0 ACTIVITY DESCRIPTION

Refurbishment of the pallet and experiment igloos will occur at the owner's site (IC, VI and VII; user, VIII). The assemblies that must be refurbished are discussed below.

Thermal control subsystem. Service pallet and igloo coolant loops, and establish the required circulation loops for the next mission. Perform a check of the system by conducting flow performance checks. Remove test circulation loops and cap/bag coolant lines.

Electrical power subsystem. Perform a functional check of the power conditioning equipment on the pallet and igloo. Remove, inspect and replace wire harness utilized for the next mission.

Structures subsystem. Remove bracketing or structural items that are not required on the next mission. Remove the attach bolts at the pallet/igloo interface and separate the dollies to examine pallet mating surfaces. Examine the mating surfaces and attach bolts for corrosion/stress cracks; clean and polish surface deteriorations; alondine surfaces, and repair as necessary. Examine both the pallet and igloo structure surfaces for stress and deterioration, and repair as required. Vacuum and clean pallet/igloo surfaces, and paint and retouch all external surfaces with thermal paint. After painting, emissivity checks will be made of all painted surfaces to verify the required thermal characteristics are present.

PALLET ONLY - CONCEPT VI - BLOCK 19.0 PCST REFURBISHMENT PALLET/IGLOO SHIPMENT

```
*******1*******2*******3*******4*******5*******6  WORKING DAYS

**   INSTALL IGLOO HATCH COVER/SEAL
****  MATE P & IGL - INSTALL/TORQUE ATTACH BOLTS - VERIFY ALIGNMENT
    *  VERIFY CURRENT PROOF LOAD OF LIFTING DEVICES
    ***  CONNECT LIFTING DEVICES TO PALLET/IGLOO
       ****  LOAD P/IGL IN SHIPPING CONTAINER ON XPORTER - TIE DOWN
         ****  INSTALL SHIPPING CONTAINER COVER - REMOVE LIFTING DEVICE
             **  MOVE P/IGL TO POINT OF EMBARKATION
               *  LOAD P/IGL ABOARD CARRIER
                *  SHIP P/IGL TO USER FACILITY
                **********  P/IGL ENROUTE
                          *  P/IGL ARRIVAL
                          ****  OFFLOAD P/IGL & XPORT TO EXPMT INTEGRATION AREA
                              *  VERIFY CURRENT PROOF LOAD OF LIFTING DEVICES
                              ***  REMOVE SHIPPING CONTAINER COVER & PRESSURIZATION
                                   UNIT
                                 ****  REMOVE P/IGL FROM XPORTER - PLACE IN FIXTURE
                                       - TIE DOWN/REMOVE LIFTING DEVICE
                                    **  REMOVE PANELS, COVERS & ACCESS DOORS -
                                        CONDUCT R/I
```


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ACTIVITY DATA SHEET

1.0 ACTIVITY IDENTIFICATION

Functional Flow Number: 19.0 Applicable Concepts: VI

Title: Post-Refurbishment, Pallet/Igloo Shipment

Principal Elements: Pallet/Experiment Igloos

2.0 ACTIVITY DESCRIPTION

In this concept (VI), the pallet and igloo are owned and maintained by the integration center (IC). After refurbishment, they are shipped to the user's facility for experiment installation and checkout. This block includes the activities relating to that shipment.

- The hatch covers and seals will be installed on the igloos and closed out.
- The pallet and igloo mechanical mating with alignment and torquing of attach bolts will be completed.
- After verification of current proof load of the lifting devices, the pallet/igloos will be loaded in the shipping container on the transporter and tied down.
- The shipping cover will be installed over the pallet/igloos. The lifting devices will be disconnected and removed. The shipping cover will be secured to the transporter. The portable pressurization unit will be activated to maintain a positive pressure within the canister during transit.
- After these pre-shipment preparations have been completed, the pallet/igloo (in their shipping canister) will be moved to the airfield and loaded aboard the air carrier for shipment to the user's facility.
- As in other concepts, two days have been utilized as the time in transit for the pallet-only (pallet/igloo). When this time period is over, the pallet/igloo will be off-loaded from the air carrier and transported to the user's experiment integration area where it will be off-loaded from the transporter. The portable pressurization units are disconnected and the

ACTIVITY DATA SHEET

2.0 ACTIVITY DESCRIPTION (CONT)

Flow Number: 19.0

shipping cover is disconnected and removed. Lifting devices are attached to the payload and it is placed in a work stand (fixture) and tied down.

- The final task will be to remove the panels, covers and access door and conduct a receiving inspection of the pallet segments and the experiment igloos to determine if there has been any damage during shipment.

E. SYSTEM COST MODEL

APPENDIX E

APPENDIX E. SYSTEM COST MODEL

1.0 INTRODUCTION

The SCM is a generalized cost compilation model applicable to any system whose elements are organized in a WBS tree (or correspondingly indentured) format. Costs are computed based on data and instructions input to the model for each element of the WBS (work breakdown structure) tree. The model then computes the costs, based on the input data, and sums the costs to each successively higher level item within the tree.

Costs may be spread by selection of a begin, peak, and end period and selection of one of five spreading curves for each element. The spreads are then summed to give total spreads for the entries at each level of the WBS tree. Each cost element in the tree may be coded to indicate cost categories such as non-recurring, recurring, operations, or other desired categories. Up to 99 categories are possible. The costs may then be summed and printed out separately for each category at each level of the WBS tree. Cost data are entered in the model, for each element to be costed, in the form of up to five numbers (A, B, C, D, and E) designating any desired parameters such as man-hours, labor rates, cost per pound, weight, etc., and by the designation of a particular equation for combining these parameters to compute cost. This procedure is illustrated in Figures E-1 and E-2.

A separate "rate card" provides for entering up to nine rates or ratios such as labor rates, overhead, procurement cost ratio, etc., on a single card and using them by reference wherever desired in the cost data inputs for the WBS elements. On successive computer runs the rates can be changed on the single card and the effect on total costs computed parametrically.

Printouts of the model are illustrated in Figures E-3 through E-6. Printouts derived from a computer run of the model can consist of either a "no-spread" printout, a "spread" printout, or both. Figure E-3 shows the cost data without the spreads. The spread printout (Figure E-4) shows the same information as in Figure E-3, except that the costs of each element are spread to periods of time as determined by the input data. Figures E-5 and E-6 show the same information as Figures E-3 and E-4, respectively, except that they include the costs in a selected cost code category only. A printout of the input data is also provided. (See Figure E-17 in the Example of Input Data section.) A technical description of the program model is contained in Section 3.0.

1. Identification of Five Costing Parameters, A, B, C, D, and E

Examples:

- Man-Hours
- Labor Rates
- Number of Personnel
- Time
- Fixed Cost Inputs
- Vendor Quotes
- CER Equation Constants
- Technical Characteristics
  - Weight
  - Thrust
  - Memory Size, etc.
- Learning Curve Value
- Complexity Factor

2. Selection of Basic Equation for Combining the Parameters

Card Type No.	
①	Cost = $(AB^C \times D) + E$
②	Cost = A x B x C x D x E
③	Cost = (A x B) + (C x D) + E
⑧	Cost Level = A x B x C x D x E for uniform spread. Cost = Cost level x length of spread.
⑨	Cost = Ratio, (A) x Cost of Another WBS Item No. (B, C, D, E)

NOTE: ④ - ⑥ not used (available for addition of new equations to program)

⑦ - Used for another purpose discussed under "Data Card Organization"

Figure E-1. Cost Data Input

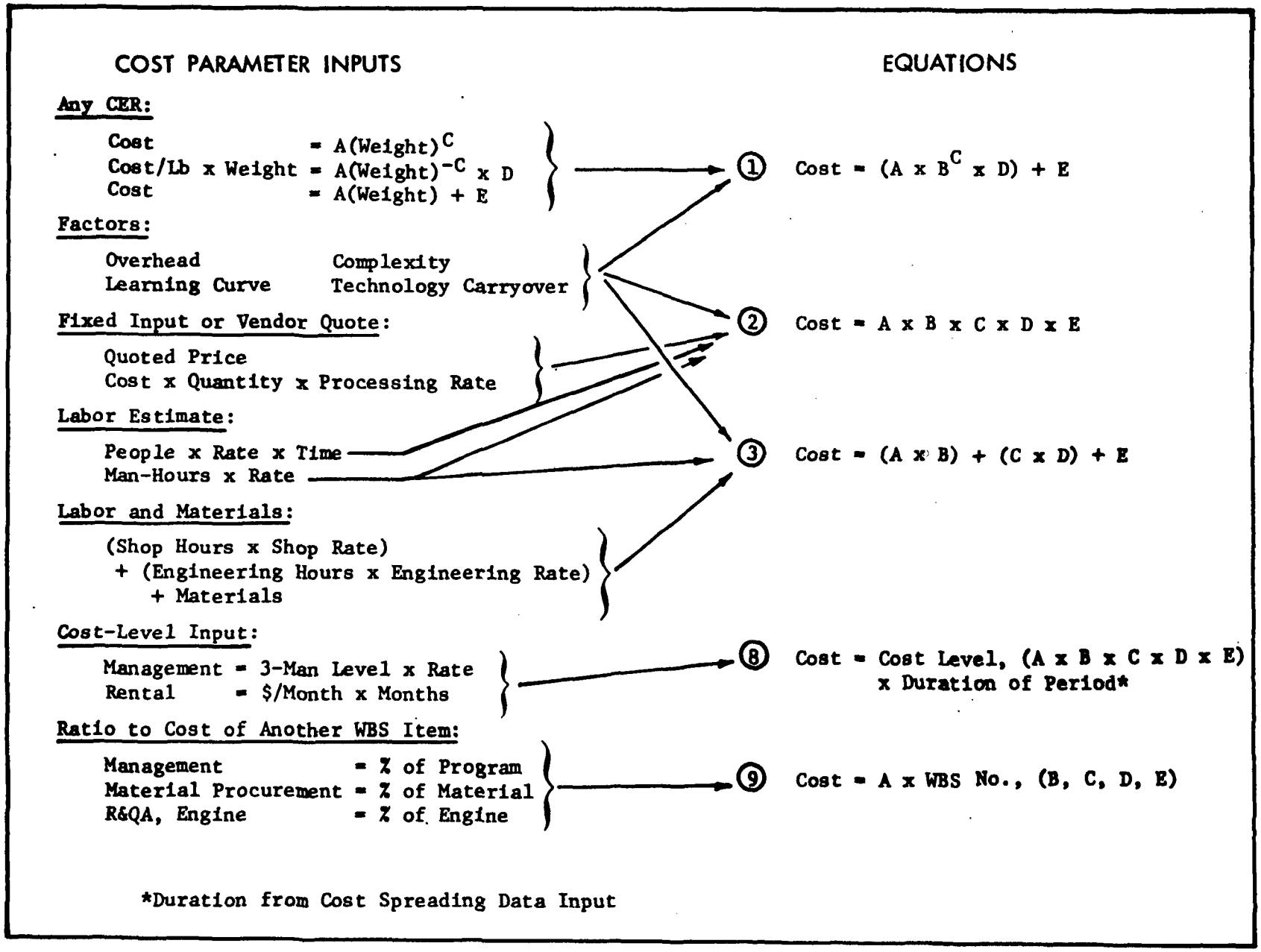

Figure E-2. Example of Cost Data Input

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RADIOMETER DEVELOPMENT PROGRAM

WBS NUMBER	ITEM	THOUSANDS OF DOLLARS	
	PROGRAM TOTAL	1920.6	
10. 0. 0. 0	ANTENNA	275.4	
1. 0. 0	ANTENNA SYSTEM DESIGN	13.5	
1. 0	SPECIFICATIONS		9.0
2. 0	TOP DRAWINGS		2.3
3. 0	INTERFACE DWGS (SL)		2.3
2. 0. 0	ANTENNA HORN	83.4	
1. 0	DESIGN DRAWINGS		12.0
2. 0	SPECIFICATIONS		6.0
3. 0	INTEGRATION (MIC)		7.5
4. 0	FABRICATION		19.2
5. 0	MATERIALS		6.9
6. 0	INSP & TEST PROCEDURES		12.0
7. 0	TESTING,RANGE & PATTERN		19.8
3. 0. 0	DEPLOY, SCAN MECHANISM	75.0	
1. 0	DESIGN DRAWINGS		12.0
2. 0	SPECIFICATIONS		6.0
3. 0	FABRICATION		14.4
4. 0	INTEGRATION		12.0
5. 0	MATERIALS		8.0
6. 0	INSP. & TEST PROCEDURES		12.0
7. 0	LAB TESTING		10.6
4. 0. 0	SUBCONTRCT SELECT & MGT	4.5	

(Continued)

Figure E-3. Sample Printout, "No-Spread"

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RADIOMETER DEVELOPMENT PROGRAM

WBS NUMBER	ITEM					THOUSANDS OF DOLLARS	
(PERIOD NO.)							
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
(17)	(18)	(					
	PROGRAM TOTAL				1920.6		
68.1	107.9	225.8	177.1	204.4	211.6	180.2	167.6
138.9	134.0	. 84.1	72.9	43.9	29.9	27.0	16.8
13.9	16.6						
10.0.0.0.0	ANTENNA				275.4		
19.3	19.7	19.6	12.3	29.1	30.6	35.0	41.2
47.4	21.2	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0						
10.1.0.0.0	ANTENNA SYSTEM DESIGN				13.5		
8.9	2.2	2.3	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0						
10.1.1.0.0	SPECIFICATIONS				9.0		
7.5	1.5	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0						

(Continued)

Figure E-4. Sample Printout With "Spread"

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RADIOMETER DEVELOPMENT PROGRAM

THIS PRINTOUT COVERS COST CODES:
CODE A = 1, DESIGN COSTS
CODE B = 0,

WBS NUMBER	ITEM	THOUSANDS OF DOLLARS	
	PROGRAM TOTAL	288.1	
10. 0. 0. 0	ANTENNA	49.5	
1. 0. 0	ANTENNA SYSTEM DESIGN	13.5	
1. 0	SPECIFICATIONS		9.0
2. 0	TOP DRAWINGS		2.3
3. 0	INTERFACE DWGS (SL)		2.3
2. 0. 0	ANTENNA HORN	18.0	
1. 0	DESIGN DRAWINGS		12.0
2. 0	SPECIFICATIONS		6.0
3. 0. 0	DEPLOY, SCAN MECHANISM	18.0	
1. 0	DESIGN DRAWINGS		12.0
2. 0	SPECIFICATIONS		6.0
20. 0. 0. 0	MOD. & INTEGRATOR CKTS.	51.0	
1. 0. 0	SPECS. (DESIGN & PERF.)	27.0	
2. 0. 0	DESIGN DRAWINGS	24.0	

(Continued)

Figure E-5. Sample Code Printout, "No-Spread"

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RADIOMETER DEVELOPMENT PROGRAM

THIS PRINTOUT COVERS COST CODES:
CODE A = 1, DESIGN COSTS
CODE B = 0,

WBS NUMBER	ITEM	THOUSANDS OF DOLLARS

(PERIOD NO.)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
(17)	(18)	(					

PROGRAM TOTAL 288.1

37.0	72.4	81.4	52.3	24.9	13.0	5.6	1.4
0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0						

10.0.0.0 ANIENNA 49.5

14.2	14.6	14.5	5.4	0.7	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0						

10.1.0.0 ANIENNA SYSIEM DESIGN 13.5

8.9	2.2	2.3	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0						

(Continued)

Figure E-6. Sample Code Printout With "Spread"

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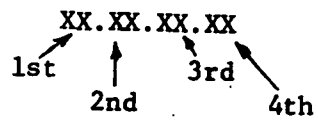
2.0 USER INSTRUCTIONS

A detailed guide for the use of the SCM is presented in this section. The model was developed primarily for cost analysis of programs that utilize a work breakdown structure for task identification and cost summations. The capacity and limitations of the program are identified with specific examples of the options of data deck organization. Available cost code categories and multi-run capabilities are defined. Alternate spreading options are also included in the model. To facilitate the usage of the model, example data inputs and common results from erroneous input data are also presented. All user instructions are based upon the implementation of the model on an IBM 360 computer with the program described in Section 3.0.

WBS TREE

The model will compute costs in four levels of a tree and sum them to a system or program total, thus covering five levels in all. The levels below the program total are called the 1st, 2nd, 3rd and 4th levels (see Figure E-7). The elements of the tree are each numbered with a four-part number designating their positions in the hierarchy.



Each part of the number contains up to 2 digits so that each item may potentially contain up to 99 items. That is, for each first-level item, the second level may contain up to 99 items. For each second-level item, the third may contain up to 99 items, etc. There is a limit, however, in the total items in the model (see Capacity of the Program).

It is not necessary to draw the tree, but only to make an indentured list of the numbers and names of the items as shown in Table E-1. The WBS may be organized in whatever manner one desires within the four levels. When costing a system, it is first necessary to break the system down into items to be costed separately and then to determine in what groupings they are to be summed to arrive at the program total cost. It should be noted that this is the function of the WBS tree.

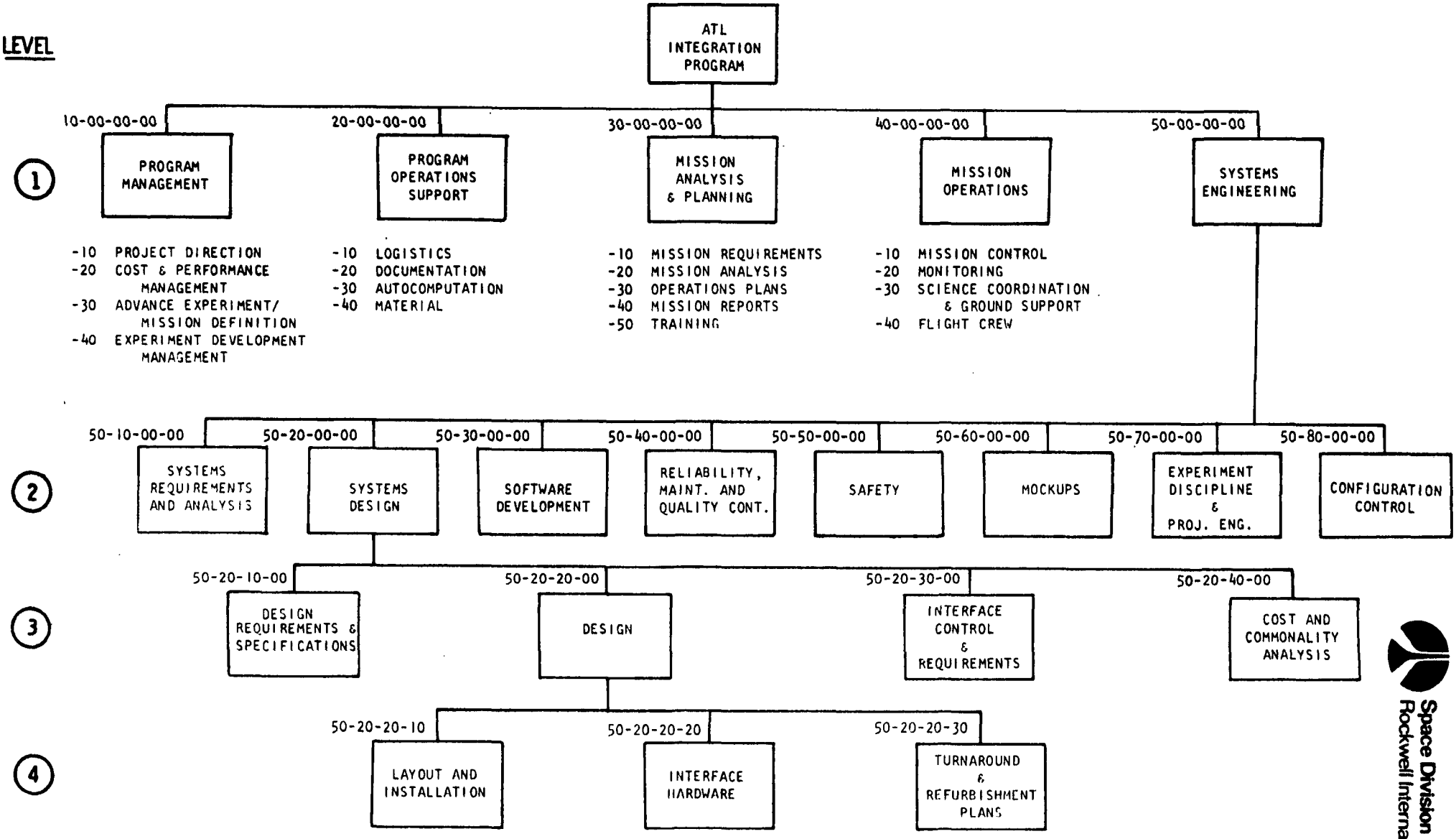


Figure E-7. Partial WBS Tree for ATL Integration Program

Table E-1. Illustrative WBS Listing

WBS Number				WBS Title
00	00	00	00	ATL INTEGRATION PROGRAM
10	00	00	00	PROGRAM MANAGEMENT
				⋮
20	00	00	00	PROGRAM OPERATIONS SUPPORT
				⋮
30	00	00	00	MISSION ANALYSIS AND PLANNING
				⋮
40	00	00	00	MISSION OPERATIONS
				⋮
50	00	00	00	SYSTEM ENGINEERING
50	10	00	00	System Requirements and Analysis
50	20	00	00	System Design
50	20	10	00	Design Requirements and Specifications
		20	00	Design
			10	Layout and Installation
			20	Interface Hardware
			30	Turnaround and Refurbishment Plans
		30		Interface Control and Requirements
		40		Cost and Commonality Analysis
50	30	00	00	Software Development
				⋮
50	40	00	00	Reliability Maintainability and Quality Control
				⋮
50	50	00	00	Safety
				⋮
50	60	00	00	Mockup
				⋮
50	70	00	00	Experiment Discipline and Project Engineering
				⋮
50	80	00	00	Configuration Control

WBS NUMBERS

The program prints out the WBS items in numerical order. Therefore, the items should be numbered sequentially. The numbers do not need to be consecutive. For example, in the first level of Figure E-7 the numbers 10, 20, 30 and 40 are used. They could have been 01, 02, 03, or 11, 12, 13. Spacing the numbers at intervals as the tree is organized gives flexibility to add intervening items and numbers later if needed. The numbers at each level are handled by the computer as two digits so that, for example, Item 30.1.2.1 must be entered in the computer as 30.01.02.01 or 30.10.20.10. Do not use initial or intervening zeros in numbering WBS items in the program levels. Start numbering each level with a 01 or higher number. That is, a WBS number should not have an initial pair of zeros nor an intervening pair. For example:

00.01.01.01 01.00.01.00 01.00.00.01	UNACCEPTABLE NUMBERS
01.01.01.00 01.01.00.00 03.00.00.00 04.01.02.00 04.01.04.00	ACCEPTABLE NUMBERS

It should be noted that only one entry per WBS number is allowable.

CAPACITY OF THE PROGRAM

The capacity of the program is nominally:

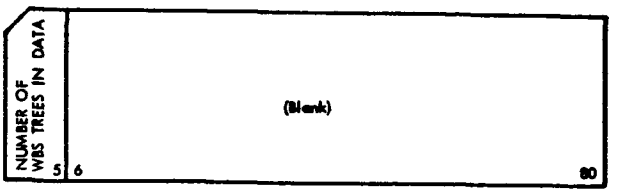
1000 WBS items (WBS cards)
24 Spreading periods
25 Card-Type 9

The Type 9 cards are for WBS items whose cost is estimated by taking a ratio to the cost of some other WBS item. Either or both the 1000 WBS items and the number of Type 9 cards can be changed by changing one or two dimension cards in the source program itself. No other changes are required. Consideration must be given, however, to the limits of computer memory: 1000 items times 24 spreading periods times the memory arrays required in the basic program require a significant memory capacity.

DATA CARD ORGANIZATION

Inputs to the program are entered on computer cards in the following manner.

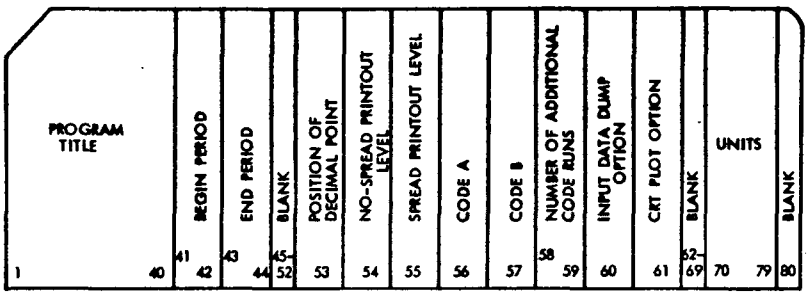
Card A - Number of Cases Card



The SCM allows operation on several different systems (organized in a WBS format) in a single computer run. There is theoretically no limit to the number of consecutive cases which can be done at once. However, the user should keep in mind the practical limits of compiling data decks, using computer time, volume of paper produced, and computer budget before chaining more than 5 to 10 cases in a single computer run.

The initial card in the data deck (Card A) must contain an integer in Columns 1 through 5, giving the number of consecutive cases to be run. This number must be right-adjusted; for example, if a single case is to be calculated the number "1" should be entered in Column 5; for 12 cases, the number "12" should be entered in Columns 4 and 5, etc. This card is not repeated. It must be the first card in the data deck, followed by complete data decks (as described in the rest of this report) for each case.

Title Card



Columns	*Item*	*Explanation*
1-40	Program Title	Name of the program to be costed such as "Radiometer Program."
41-42 43-44	Begin Period End Period	Beginning period and end period of the total program for use with cost spreads (maximum 24 periods); e.g., for 16-month program enter 01 and 16. If program covers 1976 to 1990, enter 76 and 90. The periods must be numbered consecutively.
45-52	(Not Used)	Data placed in these columns will not be read by the computer.
53	Position of Decimal	Enter 0, 1, 2, 3, 5, or 6 to determine position of decimal in printout: 0 (Dollars, man-months or other cost units) 1 Tens of (Dollars, man-months, etc.) 2 Hundreds of (Dollars, man-months, etc.) 3 Thousands of (Dollars, man-months, etc.) 5 Hundreds of Thousands of (Dollars, man-months, etc.) 6 Millions of (Dollars, man-months, etc.)

Columns	*Item*	*Explanation*
54 55	Printout Level "No Spread" Printout Level "Spread"	Enter 0, 1, 2, 3 or 4 in each column to designate the level of the WBS.

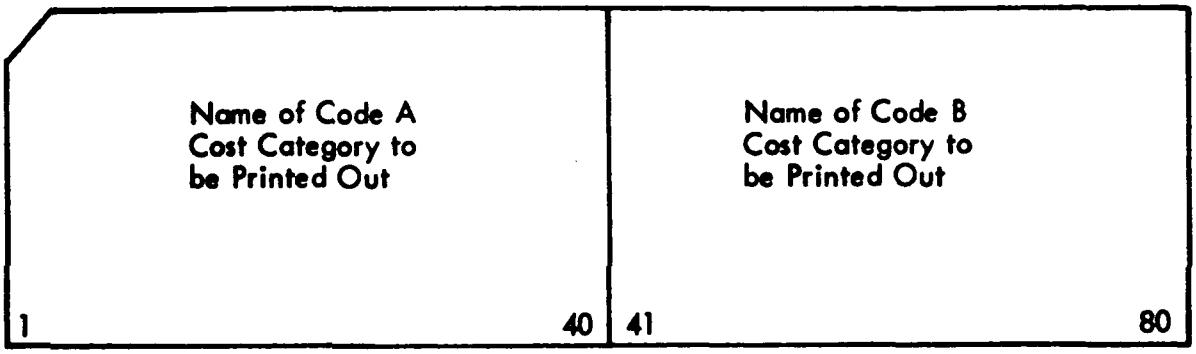
Printout

"No Spread"	"Spread"
0 No printout	0 No printout
1 Printout Level 1	1 Printout Level 1
2 Printout down to Level 2	2 Printout down to Level 2
3 Printout down to Level 3	3 Printout down to Level 3
4 Printout all levels	4 Printout all levels

For example, 0, 1 in the two columns, respectively, gives a spread printout to Level 1, but no "No Spread" printout. A 3, 4 would have a "No-Spread" printout to Level 3, and a "Spread" printout to Level 4. Any combination is acceptable except 0, 0 which would give no printout at all.

56 57	Code A Code B	Enter the code for the cost categories to be printed out on the initial run. Numbers from 0 to 9 are acceptable in each column in any combination. 0, 0 or left blank indicates codes are to be ignored and all costs are to be printed out (see "Cost Code Categories" below for explanation).
58-59	Number of Additional Code Runs	For use only if more than one cost code category printout is desired on a single run. Enter 0 to 99 for number of additional runs. See "Cost Code Categories" below for explanation. Data must be right adjusted; i.e., if less than 10, enter number in Column 59 only.
60	Input Data Printout	Enter digit 1 if it is desired to print out input data; 0 or leave blank if not.
61	CRT Plot Option	If CRT plots of spread data are desired, enter 1 and complete all other requirements described below (see "CRT Plot Option"). If no plots are desired, enter 0 or leave blank.
62-69	(Not Used)	
70-79	Units	Designates column heading to be used in printout. If model is computing costs enter word "Dollars." Enter words "Man-Months" if model is being used to compute and add man-months or whatever other units are desired.
80	(Not Used)	

Code Name Card (1A) **(To be used only when prior card called for a Cost Code Category printout)**

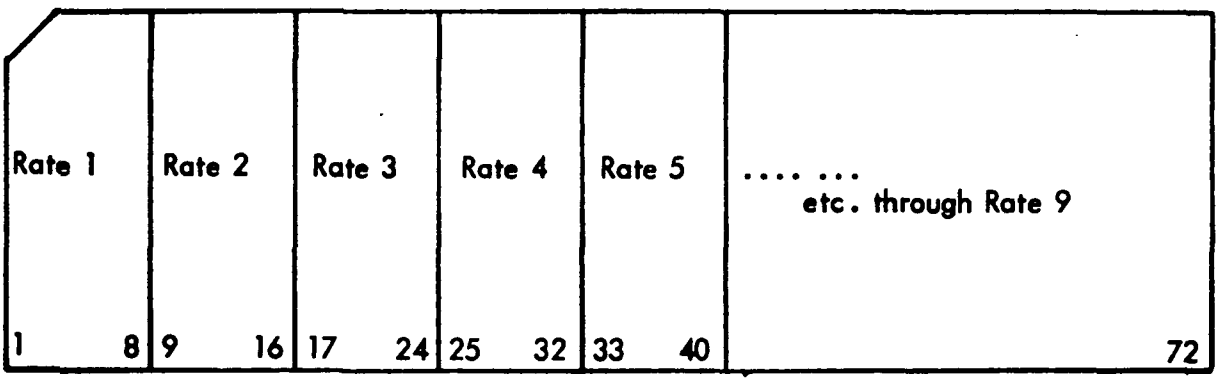


Columns

1-40 Enter the name of the Cost Code A Category indicated for printout on the prior card. If Code A were 0 on prior card, leave blank.

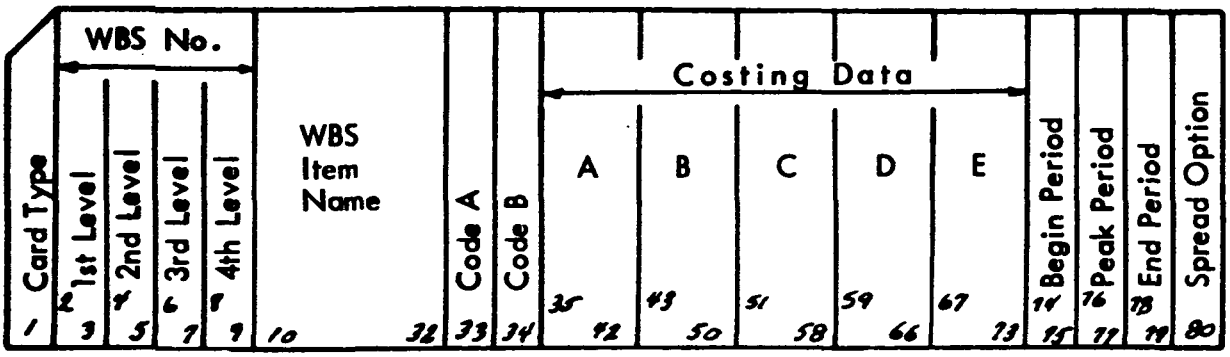
41-80 Enter the name of the Cost Code B Category indicated for printout on the prior card. If Code B were 0 on prior card, leave blank.

Rate Card



Columns	*Item*	*Explanation*
1-8	**Rate 1**	**Enter the numerical values of rates desired for reference use in costing WBS elements; e.g., 3000.0 for Engineering labor rate per man-month. Up to 7 digits, plus decimal point. Always enter the location of the decimal point.** The rate card must be included in the data deck even if the rates are not used. In this case, a blank card should be inserted for the rate card.
9-16	**Rate 2**	
17-24	**Rate 3**	
⋮	⋮	
65-72	**Rate 9**	

WBS Item Cards (One card for every item in the WBS tree, except the program total.)



Columns	*Item*	*Explanation*
1	**Card Type**	**Designates equation to be used in computing cost.**

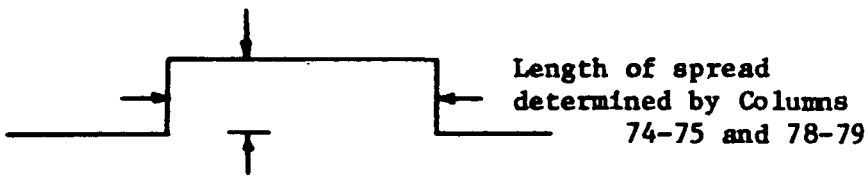
0 **None (For WBS items which are sums of other WBS items)**

1 **Cost = (A x B^C x D) + E**

2 **Cost = A x B x C x D x E**

3 **Cost = (A x B) + (C x D) + E**

8 **For use when cost level is entered into costing data. Use with spread option 4 only.**



Cost Level = A x B x C x D x E

Cost = (Cost Level) x (Length of Spread)

9 **For use when Cost is to be computed as a ratio to cost of some other WBS item.**

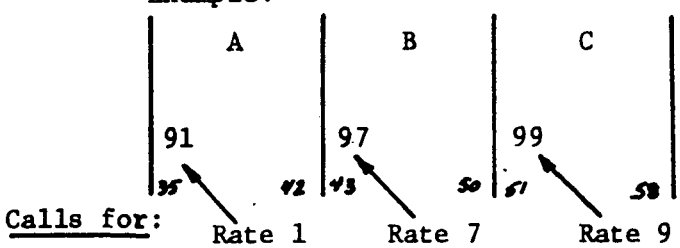
Enter desired ratio in Column A and WBS number of the other WBS item in Columns B, C, D, and E.

Example: For 15 percent of WBS item 30.01.00.00,

Enter	**A**	**B**	**C**	**D**	**E**
	.15	**30.**	**01.**	**00.**	**00.**

For 15 percent of total program cost

Enter	**A**	**B**	**C**	**D**	**E**
	.15	**00.**	**00.**	**00.**	**00.**

Columns	*Item*	*Explanation*
2-9	WBS Number	Enter the four levels of the WBS number of the item | XX | XX | XX | XX |
10-32	WBS Item Name	Enter the name of the WBS item.
33 34	Code A Code B	Enter the proper code numbers, a digit from 1 to 9 in either or both columns if costs are to be coded. See Cost Code Categories below for explanation.
35-73	Costing Data A, B, C, D, E	Enter values of parameters and constants to be used in the "Card Type" costing equations described above. See Costing example below. Always enter a decimal point in fields A, B, C, D, and E (except when calling for a Rate from the Rate card). The number with decimal point may be entered anywhere in the column. A rate may be called for from the Rate card only in Columns A, B, or C. To do this, enter a 91, 92, 93..... through 99 without a decimal point in the two furthest left columns of fields A, B, or C. Example: 
74-75 76-77 78-79	Begin Period Peak Period End Period	These columns are to be used in conjunction with the spread options of Column 80. For each WBS item, enter the period number corresponding to the beginning, peak and end of the period curve selected by Column 80 for that particular WBS item. The periods identified must be within the period of the total program defined by Columns 41 to 44 of the Title Card.
80	Spread Option	If cost spread calculations are desired, enter 1, 2, 3, 4, or 5 to select the particular spreading curve desired for each WBS item. (See "Cost Spreading Options" below for explanation.)

Final Card (for each case)

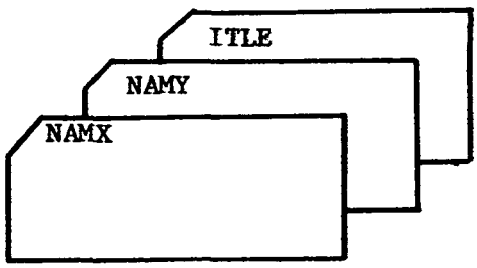
Since the program has been designed to calculate several different cases in the same computer run, there must be a card to designate the end of one case and the beginning of data for the next case. This is accomplished by placing a card with a single digit, 7, in the first column at the end of the WBS cards for each case. This card must be included for every case, including the last case.

It should be pointed out that the program has been instructed to read WBS cards until it finds a "Card Type" variable equal to 7. Thus, if any future modifications of the program are made, it is not possible to specify a cost computing equation to correspond to Card Type 7.

CRT PLOT OPTION

The SCM program has been set up with the capability to provide cathode ray tube (CRT) plots of the spread cost data if desired by the user. If no plots are desired, the user must make sure that Column Number 61 of the title card for the case is blank or contains a zero.

If plots are desired, the user must enter a "1" in Column 61 and must supply three title cards for the plots. These are illustrated below.



COLUMNS 1 - 80
ALL THREE CARDS

The data on the card "NAMX" should be the label to be placed on the X-axis of the graphs; "NAMY" is the label to be placed on the Y-axis; and "ITLE" is the title to be placed on top of the graph. A sample plot is shown in Figure E-8. Plots are produced for each spread case requested. Thus, if the user specified a spread of the total costs and spreads of five additional code runs, six plots would be produced by the computer. All six plots would have the same titles and they would be collated in the order of the regular computer printout. Thus, the user should identify the plots himself before changing their order to avoid confusion in using the data later.

The three title cards for the plots are placed directly after the title card (or first code name card, 1A, if codes are specified on the title card). They are placed ahead of the additional code run and code name card, if any.

The user should be careful to check that these cards are included in the data deck if the plot option is specified, and that they are removed from the data deck if the plot option is not desired. Failing to do this will cause the computer to find errors in the data deck.

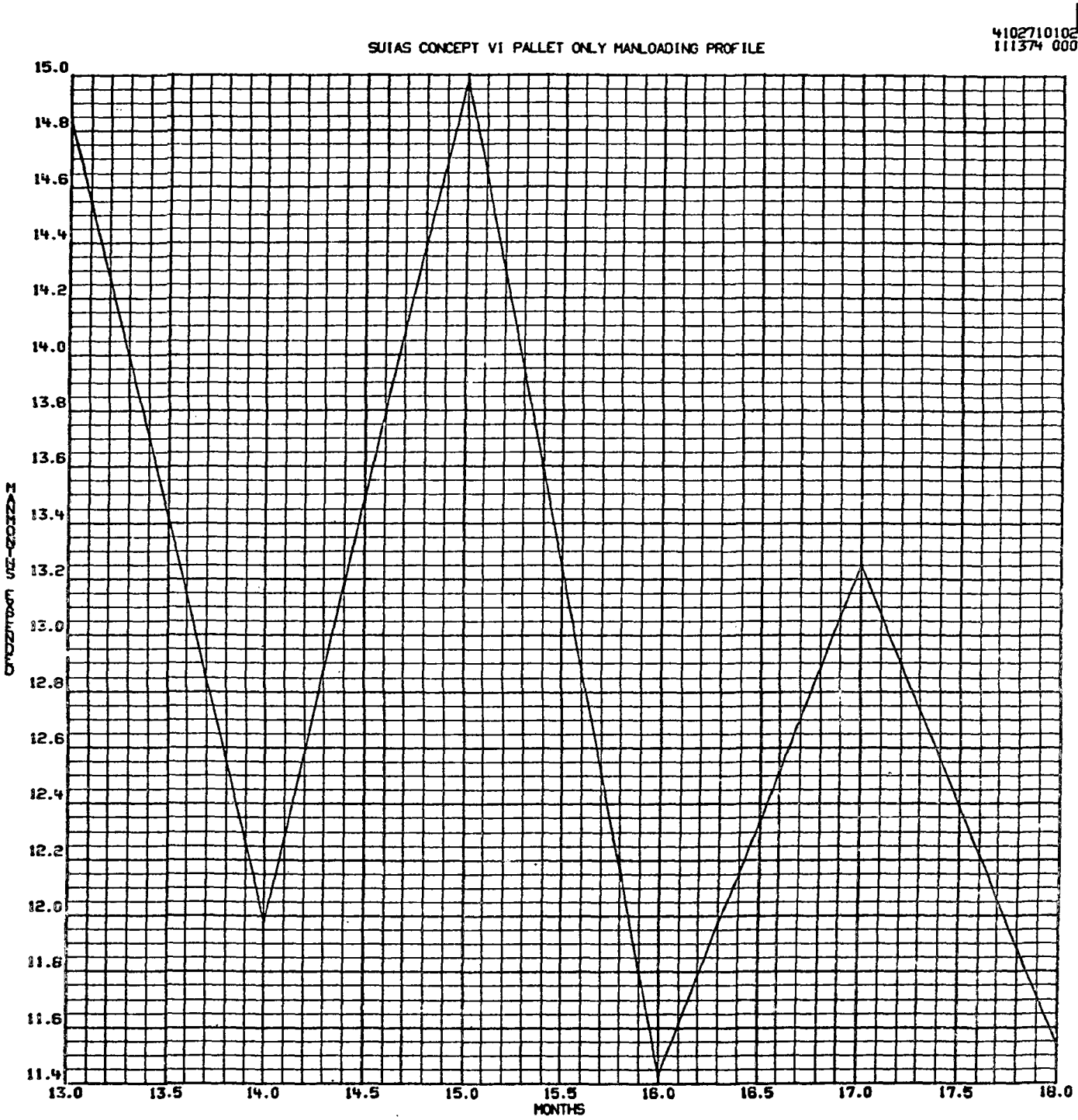


Figure E-8. Sample CRT Plot of Spread Data

COST CODE CATEGORIES

If desired, code numbers from 1 to 9 can be placed in either or both the Code A and Code B columns of each WBS item card, Columns 33 and 34. When a particular code number or combination of code numbers is called for by the title card or by additional code run cards (see below) the program will select the costs only from the WBS item cards with corresponding code numbers. These will then be printed out separately. Because 0 to 9 can be in either Column A or Column B, 100 possible code category combinations are possible. The code numbers used may be given any names desired (Code Category Name Card) and these will appear at the head of the printout.

EXAMPLE: WBS Item Cards

Enter Code A
- 1 Recurring costs
- 2 Non-recurring costs
- 3 Operations costs

Enter Code B
- 1 Engineering department costs
- 2 Test and operations department costs

The following entries may then be used on the title card (or additional code run cards) calling for a code printout:

Column 56 - 0, 1, 2 or 3
Column 57 - 0, 1, 2

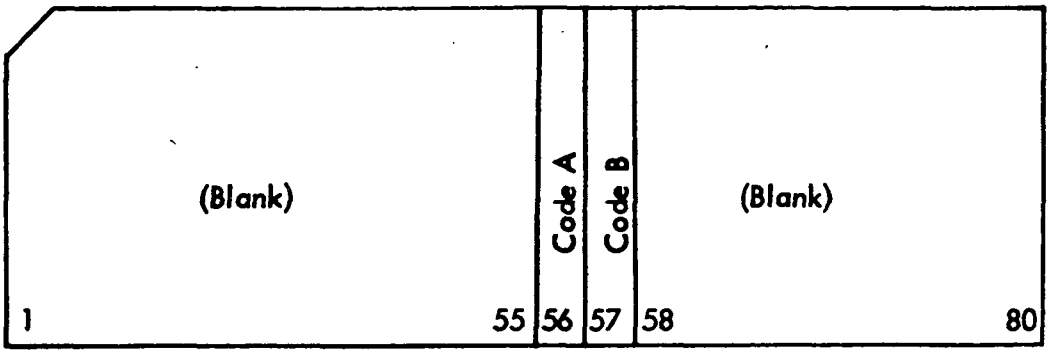
A 0, 0 in the two columns, respectively, means that the codes are ignored and all costs are printed.

1,0 gives all recurring costs
1,1 gives recurring engineering department costs
0,1 gives all engineering department costs
⋮
3,0 gives all operations costs
3,2 gives operations costs incurred by the test and operations department only.
⋮
etc.

ADDITIONAL CODE RUN CARDS

If it is desired to have more than the single printout called for by the "Title Card," additional code printouts can be obtained in a single computer run by entering the number of desired additional runs in the "Additional Code Runs" column numbers 58-59 of the title card, and by adding the same number of "Additional Code Run Cards" and "Code Name Cards" alternately after the Title Card (and the initial "Code Name Card," if any), or after the CRT plot title cards if the CRT plot option is specified.

Additional Code Run Card



The additional code run card is a blank card except for digits in Columns 56 and/or Column 57 calling for a particular code category printout.

Up to 99 additional code run cards can be inserted ahead of the rate card. Each must be followed by a "Code Name Card" giving the desired names of the codes used. The code name for Code A is entered in Columns 1-40 and the code name for Code B is entered in Columns 41-80 as illustrated for Card 1A previously.

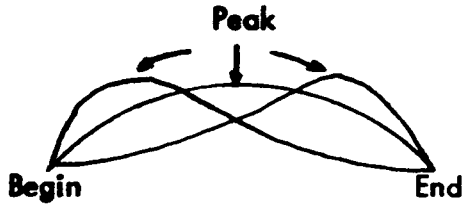
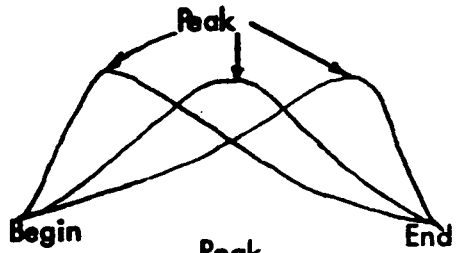
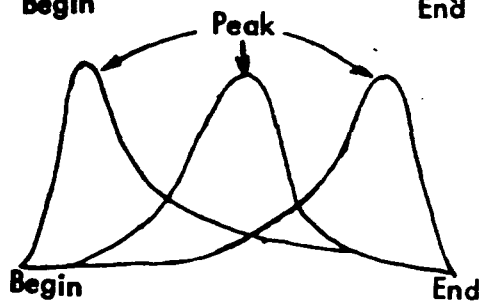
The number of additional code run cards used must always be entered in Columns 58-59 of the title card.

It should be noted that due to the logic of the summing routines in the program that a code run with Codes A and B equal to zero (for a total sum of all costs) is not acceptable on the additional code run cards. If a printout of total costs is desired, it must be specified on the title card by having both codes on that card equal to zero and eliminating Card 1A, the code name card for the title card codes. The additional code run cards must have at least one of the codes greater than zero.

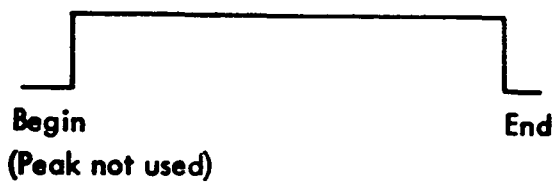
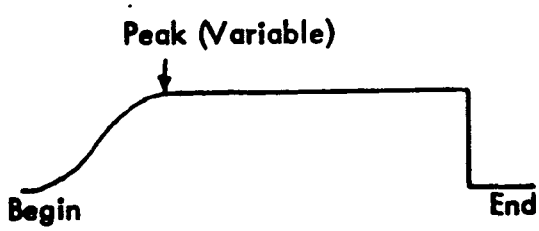
SPREADING OPTIONS (Columns 74-79 of WBS Item Cards)

Five spreading option curves are available for use in the model. These are selected by entering 1, 2, 3, 4 or 5 in Column 80 of the WBS item cards. The length of each spread is determined by entering the begin and end period numbers on the WBS item cards. The location of the peak may be varied by designation of the peak period for the bell-shaped curves 1, 2 and 3. The location of the top of the initial slope may be designated for Curve 5.

The spreading option curves are shown in Figure E-9.

Spreading Option Number		
1	Bell-Shaped Low Profile	
2	Bell-Shaped Nominal Profile	
3	Bell-Shaped High Profile	

For Curves 1, 2 and 3, costs begin at the beginning of the Begin period and end at the end of the End period. The peak occurs at the middle of the Peak period. The peak can be no less than 10 percent of distance from beginning or end.

4	Uniform Spread	
5	Uniform Spread with Initial Buildup Slope	

For Curve 5, costs begin at beginning of Begin period and end at end of End period. The flat part of curve begins at beginning of Peak period.

Figure E-9. Spreading Options Curves

ARRANGEMENT OF DATA CARDS FOR COMPUTER RUNS

The user has been provided with a number of options in the use of the SCM program. The options which affect the actual arrangement of the data deck (rather than specific data on individual data cards) are as follows.

1. Printout with or without individual code runs for each case. (Up to 99 different code runs may be obtained.)

2. Program may be run with or without CRT graphs for each of the individual cases.

3. Program may be run with any number of individual cases chained in a single data deck.

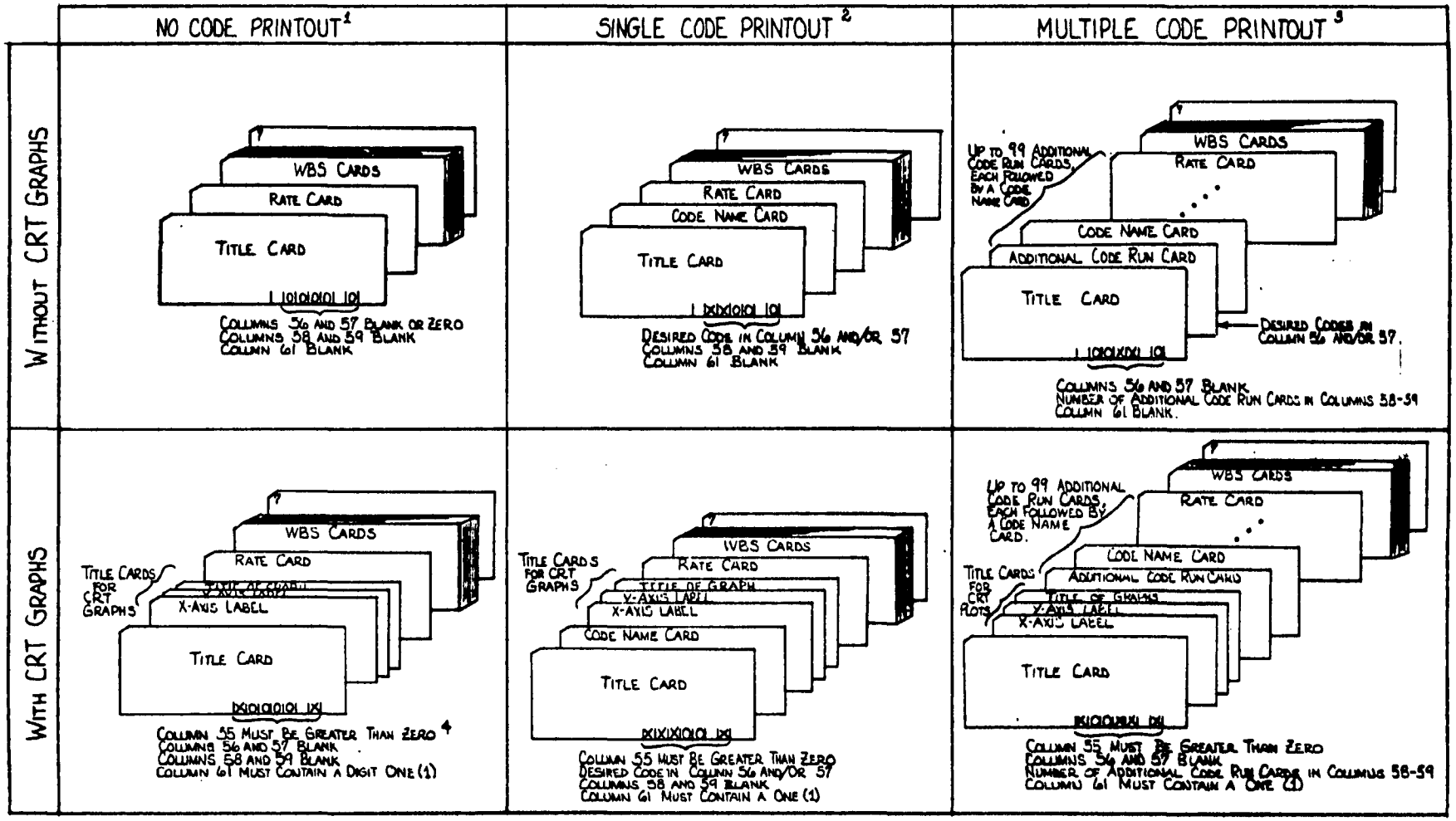
Figure E-10 illustrates the various options for setting up a data deck for an individual case (Options 1 and 2 above). Figure E-11 then illustrates the arrangement of individual cases in a complete data deck with Option 3 above. Figure E-12 shows the complete Fortran deck arrangement including the program decks and control cards as well as the data.

EXAMPLE OF DATA INPUT

Figure E-13 shows a data sheet prepared for punching of the WBS Item computer cards. The figure will be used for illustrating cost data and other data inputs. The figure (which is only illustrative) covers the input for the electronic subsystem which is a portion of a radiometer instrument proposed to be carried by a spacecraft. This portion of the WBS tree would appear as in Figure E-14. The entries for the WBS items are discussed below following an explanation of the required title and rate cards. A printout of the data based on Figure E-13 is shown in Figures E-15 and E-16. Printout of the input data is shown in Figure E-17.

Title Card (Example)

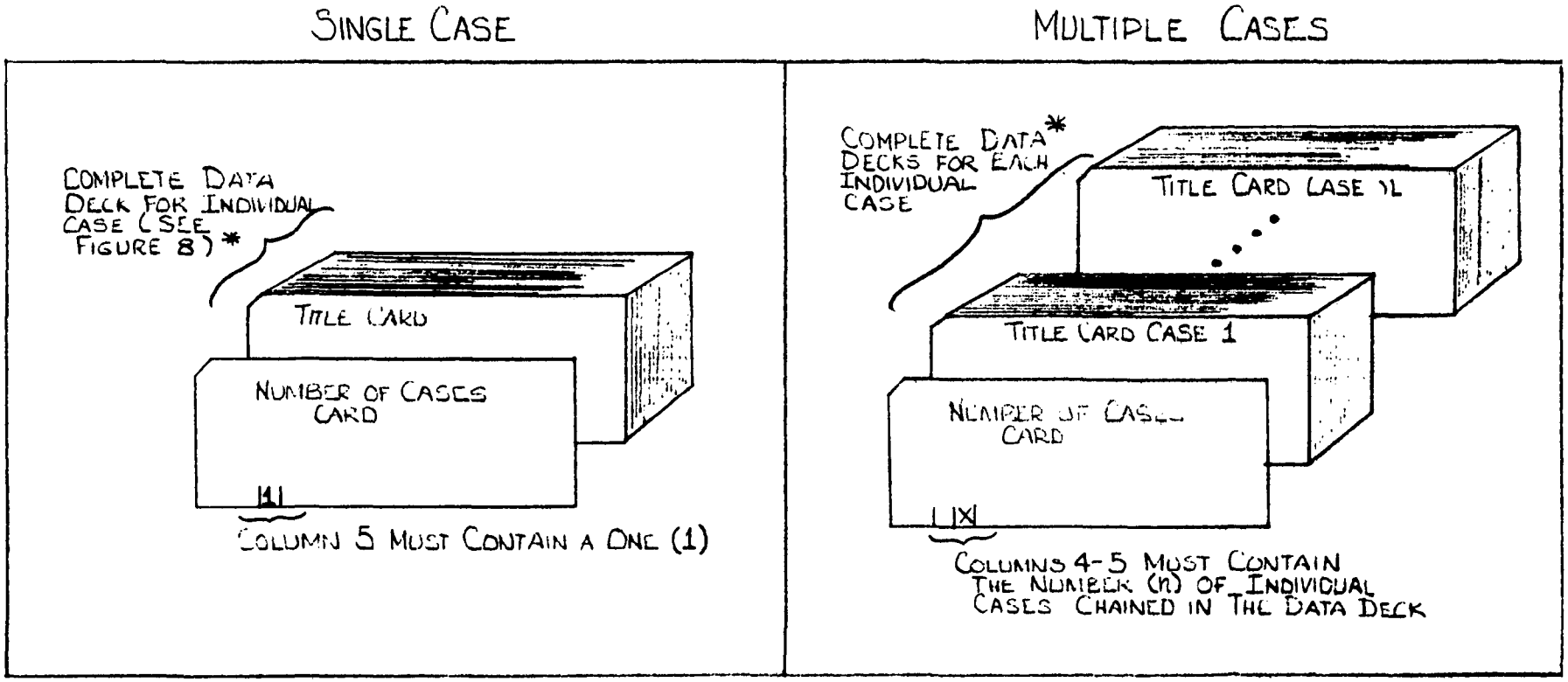
Entry	*Column Numbers*	
RADIØMETER PRØGRAM	1-40	Program Title
01	41-42	Begin Period
18	43-44	End Period
3	53	Position of Decimal (to read out in thousands)
4	54	Printout Level, No Spread
4	55	Printout Level, Spread (to print out costs down through the 4th level for both a Spread and a No-Spread printout)
0	56	Code A (See explanation on page E-20)
0	57	Code B (See explanation on page E-20)
00	58-59	Additional Code Runs
1	60	Input Data Printout desired
0	61	No Plots Desired
DØLLARS	70-79	Units



NOTES:

1. Would Produce A Printout Of The Total Costs Only
2. Would Produce A Printout Of A Single Code Only, No Total Cost Printout Would Be Generated
3. Would Produce A Printout Of Total Costs And Totals For Each Cost Code Given On The Additional Code Run Cards
4. Plots Can Be Produced Only If Cost Spreads Are Requested To At Least One Level

Figure E-10. Data Card Organization for Individual Cases



*EACH CASE CAN BE ANY ONE OF THE OPTIONS ILLUSTRATED IN FIGURE E-10.

Figure E-11. Complete Data Deck Arrangement

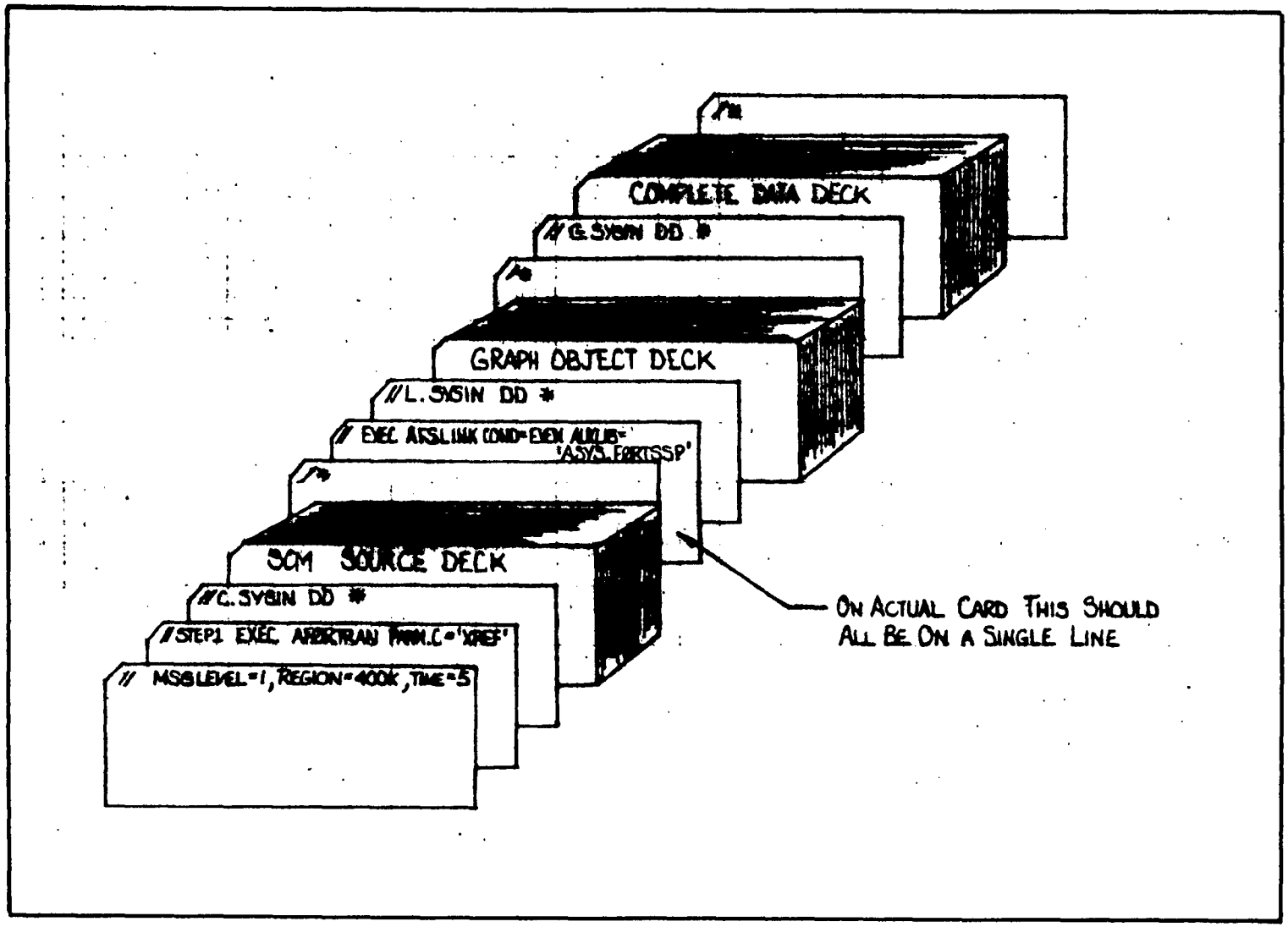


Figure E-12. Arrangement of Entire Deck Including Job Control Language Cards (JCL)

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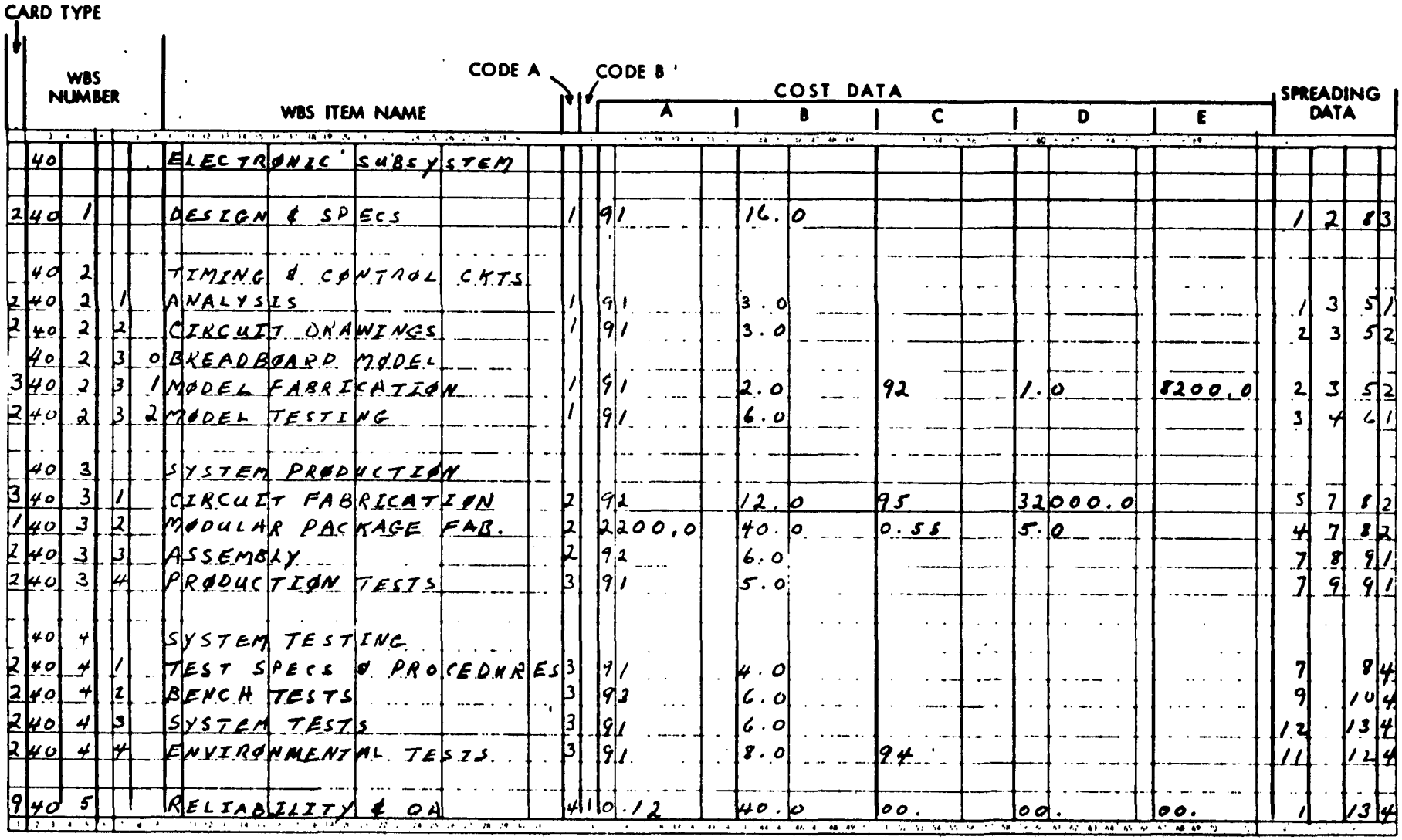

CARD TYPE	WBS NUMBER	WBS ITEM NAME	CODE A	CODE B	COST DATA A	COST DATA B	COST DATA C	COST DATA D	COST DATA E	SPREADING DATA
	40	ELECTRONIC SUBSYSTEM								
2	40 1	DESIGN & SPECS	1		91	16.0				1283
	40 2	TIMING & CONTROL CKTS								
2	40 2 1	ANALYSIS	1		91	3.0				1351
2	40 2 2	CIRCUIT DRAWINGS	1		91	3.0				2352
	40 2 3 0	BREADBOARD MODEL								
3	40 2 3 1	MODEL FABRICATION	1		91	2.0	92	1.0	8200.0	2352
2	40 2 3 2	MODEL TESTING	1		91	6.0				3461
	40 3	SYSTEM PRODUCTION								
3	40 3 1	CIRCUIT FABRICATION	2		92	12.0	95	32000.0		5782
1	40 3 2	MODULAR PACKAGE FAB.	2		2200.0	40.0	0.55	5.0		4782
2	40 3 3	ASSEMBLY	2		92	6.0				7891
2	40 3 4	PRODUCTION TESTS	3		91	5.0				7991
	40 4	SYSTEM TESTING								
2	40 4 1	TEST SPECS & PROCEDURES	3		91	4.0				784
2	40 4 2	BENCH TESTS	3		92	6.0				9104
2	40 4 3	SYSTEM TESTS	3		91	6.0				12134
2	40 4 4	ENVIRONMENTAL TESTS	3		91	8.0	94			11124
9	40 5	RELIABILITY & QA	4	1	0.12	40.0	00.	00.	00.	1134

Figure E-13. Example Data Input Sheet for WBS Cards

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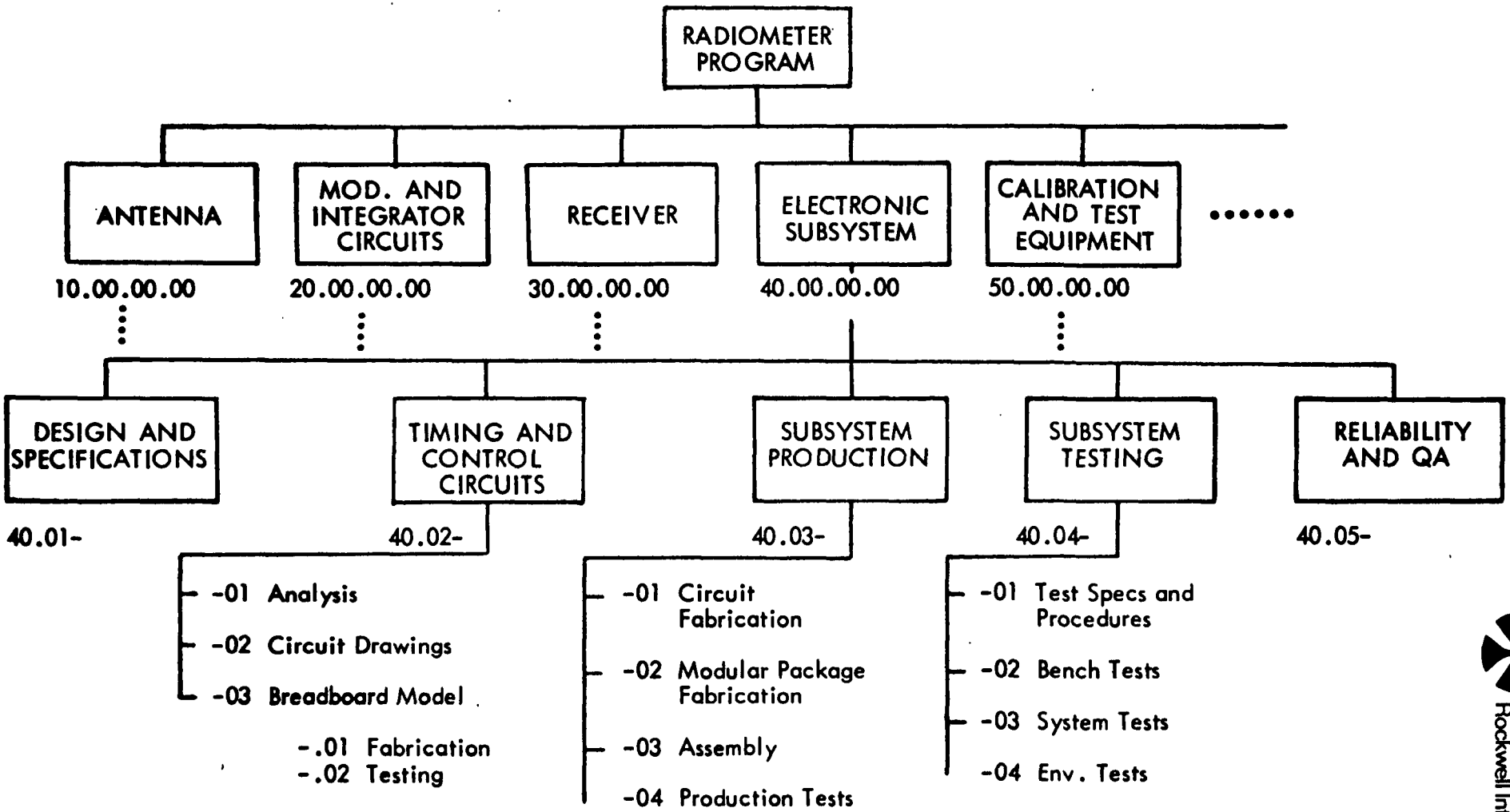

Figure E-14. Example WBS Tree, Electronic Subsystem Portion

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RADIOMETER DEVELOPMENT PROGRAM

(ELECTRONIC SUBSYSTEM ONLY)

WBS NUMBER	ITEM	THOUSANDS OF DOLLARS		
	PROGRAM TOTAL	397.4		
40. 0. 0. 0	ELECTRONIC SUBSYSTEM	397.4		
1. 0. 0	DESIGN & SPECS.		48.0	
2. 0. 0	TIMING & CONTROL CKTS		52.6	
1. 0	ANALYSIS		9.0	
2. 0	CIRCUIT DRAWINGS		9.0	
3. 0	BREADBOARD MODEL		34.6	
1	MODEL FABRICATION			16.6
2	MODEL TESTING			18.0
3. 0. 0	SYSTEM PRODUCTION		178.7	
1. 0	CIRCUIT FABRICATION		65.6	
2. 0	MODULAR PACKAGE FAB.		83.7	
3. 0	ASSEMBLY		14.4	
4. 0	PRODUCTION TESTS		15.0	
4. 0. 0	SYSTEM TESTING		75.6	
1. 0	TEST SPECS & PROCEDURES		12.0	
2. 0	BENCH TESTS		19.2	
3. 0	SYSTEM TESTS		18.0	
4. 0	ENVIRONMENTAL TESTS		26.4	
5. 0. 0	RELIABILITY & QA		42.6	

Figure E-15. Sample Cost Printout (No Spread)

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RADIOMETER DEVELOPMENT PROGRAM

(ELECTRONIC SUBSYSTEM ONLY)

WBS NUMBER	ITEM	THOUSANDS OF DOLLARS

(PERIOD NO.)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
(17)	(18)	(					

PROGRAM TOTAL 397.4

13.5	26.3	34.1	27.0	26.6	49.0	75.7	53.8
24.3	12.9	16.5	25.5	12.3	0.0	0.0	0.0
0.0	0.0						

40.0.0.0 ELECTRONIC SUBSYSTEM 397.4

13.5	26.3	34.1	27.0	26.6	49.0	75.7	53.8
24.3	12.9	16.5	25.5	12.3	0.0	0.0	0.0
0.0	0.0						

40.1.0.0 DESIGN & SPECS 49.0

9.0	15.3	12.4	7.2	3.1	0.9	0.1	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0						

40.2.0.0 TIMING & CONTROL CKTS 52.6

1.2	7.9	18.4	15.4	7.3	2.5	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0						

Figure E-16. Sample Cost Printout, With Spread (First Page Only)

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INPUT DATA

TYPE	WBS NO.	NAME	CODE	A	B	C	D	E	B	P	E	S
0	40. 0. 0. 0	ELECTRONIC SUBSYSTEM	00	0.0	0.0	0.0	0.0	0.0	0	0	0	0
2	40. 1. 0. 0	DESIGN & SPECS.	10	91000.00	16.00	0.0	0.0	0.0	1	2	8	3
0	40. 2. 0. 0	TIMING & CONTROL CKTS	00	0.0	0.0	0.0	0.0	0.0	0	0	0	0
2	40. 2. 1. 0	ANALYSIS	10	91000.00	3.00	0.0	0.0	0.0	1	3	5	1
2	40. 2. 2. 0	CIRCUIT DRAWINGS	10	91000.00	3.00	0.0	0.0	0.0	2	3	5	2
0	40. 2. 3. 0	BREADBOARD MODEL	00	0.0	0.0	0.0	0.0	0.0	0	0	0	0
3	40. 2. 3. 1	MODEL FABRICATION	10	91000.00	2.00	92000.00	1.00	8200.00	2	3	5	2
2	40. 2. 3. 2	MODEL TESTING	10	91000.00	6.00	0.0	0.0	0.0	3	4	6	1
0	40. 3. 0. 0	SYSTEM PRODUCTION	00	0.0	0.0	0.0	0.0	0.0	0	0	0	0
3	40. 3. 1. 0	CIRCUIT FABRICATION	20	92000.00	12.00	95000.00	32000.00	0.0	5	7	8	2
1	40. 3. 2. 0	MODULAR PACKAGE FAB.	20	2200.00	40.00	0.55	5.00	0.0	4	7	8	2
2	40. 3. 3. 0	ASSEMBLY	20	92000.00	6.00	0.0	0.0	0.0	7	8	9	1
2	40. 3. 4. 0	PRODUCTION TESTS	30	91000.00	5.00	0.0	0.0	0.0	7	9	9	1
0	40. 4. 0. 0	SYSTEM TESTING	00	0.0	0.0	0.0	0.0	0.0	0	0	0	0
2	40. 4. 1. 0	TEST SPECS & PROCEDURES	30	91000.00	4.00	0.0	0.0	0.0	7	0	8	4
2	40. 4. 2. 0	BENCH TESTS	30	93000.00	6.00	0.0	0.0	0.0	9	0	10	4
2	40. 4. 3. 0	SYSTEM TESTS	30	91000.00	6.00	0.0	0.0	0.0	12	0	13	4
2	40. 4. 4. 0	ENVIRONMENTAL TESTS	30	91000.00	8.00	94000.00	0.0	0.0	11	0	12	4
9	40. 5. 0. 0	RELIABILITY & QA	41	0.12	40.00	0.0	0.0	0.0	1	0	13	4

WBS Item Data

Printed out if 1 in Col. 59 of Title Card

RADIOMETER-ELECTRONIC SUBSYSTEM
KBP= 1 KEP= 18 KPD= 3 KPONS= 4
KPOS= 4 KUDEA= 0 KUDEB= 0 NAR= 0

THE RATES USED ARE:

0.300E+04	0.240E+04	0.320E+04	0.110E+01	0.115E+01
0.0	0.0	0.0	0.0	

THE CODES USED ARE:
A = 0 0 0 0 0 0 0 0 0 0
B = 0 0 0 0 0 0 0 0 0 0

Title and Code Card Data

Always printed at end of printout

Figure E-17. Sample Input Data Printout

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Codes used in Columns 33 and 34 of the WBS item cards (Figure E-13) for the example radiometer program were as follows.

Code A		Code B	
1	Design and Development	1	Reliability and QA Costs
2	Fabrication	2	Management Costs
3	Testing		
4	Other Costs		

The 0,0 in Columns 56 and 57 of the title card provides that the codes will be ignored. A 1,0 would have called for printout of just the items coded "1" in Column 33 of the WBS cards. A code name card would then have been required. (see Cost Code Category section).

Rate Card (Example)

The WBS entries in Figure E-13 are based on a rate card filled out as follows.

Entry	*Column Numbers*	*Item*
3000.0	0-8	Rate 1 - Engineering Labor Rate per Month
2400.0	9-16	Rate 2 - Shop Labor Rate per Month
3200.0	17-24	Rate 3 - Lab Labor Rate per Month
1.10	75-32	Rate 4 - Factor for Use of Environmental Lab Equipment
1.15	33-40	Rate 5 - Factor for Material Procurement Costs

The factors 1.10 and 1.15 are used in the example (Figure E-13) to reflect a 10-percent and 15-percent surcharge, respectively, for use of the environmental test lab and for purchasing department costs in connection with material procurement costs.

WBS Cards (Example)

In filling out the WBS item card data it is not necessary to enter the zeros in the WBS numbers, Columns 2-9 of Figure E-13, because a blank is read as a zero. Note that cost data, codes, and spreading data are not required for those items for which costs are simply the sums of lower-level costs. Examples of this are the following items: 40.-, Electronic Subsystem; 40.02, Timing and Control Circuits; 40.02.03, Breadboard Model; etc. These are called "basket" cards because they are items in which lower-level costs are accumulated. Data must be entered for all items which are not sums of lower-level items, i.e., all cards except basket cards. DO NOT enter cost data for basket cards.

The cost codes entered in Columns 33 and 34 are explained above in connection with entries on the title card.

Cost Data (Example)

The first entry to be costed is 40.01, Design and Specifications, which is estimated as requiring 16 man-months of engineering effort. The 91 at the extreme

left of the A-field (without a decimal) picks up Rate 1, which is the engineering labor rate, from the rate card. The "2" in Column 1 designates the Card Type 2 equation, which is

$$\text{Cost} = A \times B \times C \times D \times E$$

It is not necessary to fill a "1" in Columns C, D, or E because, for Card Type 2, the program automatically enters a "1" when any of the fields A, B, C, D, or E are blank.

Item 40.02.03.01, Model Fabrication, uses the Card Type 3 equation, which is

$$\text{Cost} = (A \times B) + (C \times D) + E$$

Here, it was estimated that the items would require two man-months of engineering labor plus one man-month of shop labor plus 8200 dollars in materials. The material could have been broken out as a separate WBS item. This would have been the possible solution to be used, for example, if it were desired to multiply the material procurement by a ratio to reflect a surcharge for procurement department costs.

Item 40.03.01, Circuit Fabrication, also uses the Card Type 3 equation, Cost = (A x B) + (C x D) + E. Here, the item was estimated to require 12 man-months of shop labor plus $32,000 in material costs. The 92 in the A-field picks up Rate 2 which is the shop labor rate. The 95 in the C-field picks up Rate 5, which is 1.15. This adds 15 percent for purchasing department costs to the costs of the material. (Note that rates from the rate card can be picked up in fields A, B, and C only--not in D or E.)

Item 40.03.02 is costed using a conventional cost estimating relationship (CER):

$$\text{Cost} = 2200\ (\text{weight})^{0.55}$$

Card-Type Equation 1, Cost = $(AB^C \times D) + E$, is used. The value of B = weight is 40 pounds, estimated for the item. There are five modules designed and fabricated. The equation appears as a straight line when plotted on log-log paper.

Item 40.04.04, Environmental Testing, is estimated at 8 man-months of engineering effort which is multipled by Rate 4 = 1.10, which is used to add to the item a 10-percent surcharge for use of equipment in the environmental test lab.

The last item is 40.05, Reliability and Quality Assurance; it is estimated at 12 percent of the other electronic subsystem costs. This is accomplished by entering 0.12 in field A and the WBS number of the electronic subsystem (40.00.00.00) in fields B, C, D and E. Note all entries in the A to E fields must have decimal points except when using 91 through 99 to call for the rates from the rate card.

Cost Spreading Option (Example)

The cost spreading data are entered in Columns 74 through 80 of Figure E-13 for each WBS item. It was estimated that the total program would last 3 years, or 36 months. The spreads handle only up to 24 periods so each period was designated as 2 months long, making 18 periods for the program. The numbers, 01 to 18, were entered in Columns 41-42 and 43-44, respectively, of the title card to define the period of the total program. The electronic subsystem was to be ready for integration with the rest of the system by the 26th month, which is in the 13th period.

The spreading option entries are defined in the section entitled "Spreading Options." For example, Item 40.01, Design and Specifications, starts in the first 2-month interval, peaks in the second 2-month interval, and is completed in the eighth 2-month interval. It uses a Type-3 curve which peaks sharply in the second 2-month interval. A "3" for the Type-3 curve is entered in Column 80.

An example of the first page of the cost spread printout is shown in Figure E-16.

Previous discussion has indicated the utilization of SCM for costing of a program. The SCM can also be effectively used for the compilation of man-months of effort of a program. As noted in the explanation of the "Title Card" Columns 70-79 are used to specify units. Insertion of "man-months" will result in all data being presented in this unit. Rate Columns B, C, D, and E (43 through 72) on each WBS card are left blank. Man-months for each WBS task are entered in Rate Column A (36-40) left-adjusted. The decimal point must be included in the number. Entry of man-month estimates are shown below.

Column No.	36	37	38	39	40	41	42	
	1	0	0	.				→ 100 man-months
	9	.						→ 9 man-months
	4	8	6	5	.			→ 4865 man-months

Cost Code Columns A and B (33 and 34) can be effectively used for multiple organization and skill code compilations. A commonly used set is shown below.

Column 33 Let 1 = User Center
2 = Integration Center
3 = Launch Site

Column 34 Let 1 = Operations Analyst
2 = Systems Engineer
3 = Designer
4 = Programmer
5 = Coder
6 = Test Engineer
7 = Test Technician
8 = Mechanic
9 = Administrative Assistant

Thus, the manpower estimates for a given WBS task can be compiled by SCM for combinations of centers and skill codes. Also, the composite Code A (Center Summary) and Code B (Skill Code Summary) requirements can be compiled by SCM.

The same precaution in the use of SCM for the purpose of compiling cost data applies to compilation of manpower estimates--only one entry per WBS identifier is allowed. Therefore, if multiple-center and/or multiple-skill codes are required for a specific task a separate WBS number must be used for each entry. Using an XO.XO.XO.XO WBS format rather than OX.OX.OX.OX will readily accommodate multiple entries. Each entry at a particular WBS level is sequentially numbered in the last digit of that level. Summation occurs at the next highest level of the WBS.

INPUT DATA ERRORS

The program will print out an error message for certain types of input data errors. These should be watched for because the program continues in order to detect additional errors, if any, and to yield some (though erroneous) results. A typical format of the notation is "Error on WBS Card No. ___." Examples are as follows.

• Nonexistant card type	- Item cost remains zero. Program continues.
• Nonexistant spread option	- Option 2 is substituted. Program continues.
• Unacceptable WBS number (i.e., intervening errors or duplicate WBS numbers)	- Results in erroneous summing. Program continues; a list of WBS numbers also prints out to assist in finding the error.

Input data should be carefully prepared because the program cannot catch most errors. Input errors may result in errors only in individual WBS items or they may result in erroneous summing logic and affect cost totals. The latter is the case with most errors in WBS numbers.

A check of the following items will avoid certain types of errors:

1. Be sure there is always a basket WBS item (with the WBS number ending in zero or zeros) to provide a place for the sum of any subsidiary WBS item costs.

2. Do not enter cost data for basket items. A, B, C, D and E must be zero for basket items, otherwise code printouts will be in error.

3. Do not use the same WBS number twice.

4. Check the spread data to be sure all WBS item spread periods are within the total program spread. Be sure the peak period is not outside the Begin and End periods, and that the End period is greater than the Begin period.

5. A code printout entry of 0,0 is acceptable on the title card only (Columns 56 and 57). Additional code run cards must have a code ≥ 1 in Column 56 and/or 57.

6. Be sure code name card or cards are provided whenever code is ≥ 1 in either Column 56 or 57 on the title card or additional code run cards.

7. Be sure to enter a decimal point when entering cost data in the A, B, C, D or E fields of the WBS item cards except when calling for a rate. Never use a decimal with the numbers 91 through 99 when calling for a rate.

3.0 TECHNICAL DESCRIPTION OF SYSTEM COST MODEL

This section contains a technical description of the SCM model. Symbols used in the program, a detailed flow chart, and a listing of the source program are contained in Annexes A, B, and C, respectively, to this appendix. The program is written in basic Fortran. Numbers on the steps of the flow chart refer to steps in the program listing. Instructions for use of the model are presented in Section 2.0.

PROGRAM ORGANIZATION

The overall organization of the program is illustrated in Figure E-18. The entire program has been placed inside a "DO LOOP" which permits repetition of the model for any number of individual cases in a single computer run. The discussion of the program organization and input data cards in this appendix apply to each individual case which would be processed in a multiple case run. Data on the title card, the rate card, and the code name and additional code run cards (if used) are read into the computer at the beginning of the program after the arrays are dimensioned and other preliminaries are completed. The WBS item cards are read next. As each WBS item card is read, a counter "N" is incremented by one so that each card is initially numbered with a value of N as it is read into the computer. Thereafter, all data associated with each WBS item card, including the WBS numbers, are stored and identified by the initial value of N associated with each card. For example, COST(N) becomes the cost of the Nth WBS item when it is computed. NAME(N,J) becomes the name of the Nth WBS item. (The J subscript is necessary to provide storage for 23 letters of the name.) When the last card is read, NC is set equal to N so that NC is the total number of WBS cards read.

As the WBS item cards are read, costs and cost spreads (when required) are computed for each card except Type-9 cards before the next card is read. This eliminates the need to store much of the WBS card input data, thus saving computer memory space which is already necessarily large to handle the costs and cost spreads. Type-9 card costs are computed by taking a ratio to the cost of some other WBS item. It is therefore necessary to both compute costs and sum the costs for all other cards before Type-9 card costs are computed. Input cost and cost spread data are therefore stored for the Type-9 cards until after the initial summing routines are completed. As each Type-9 card is read, a counter, "NG" (as well as the "N" counter), is incremented so that each Type-9 card is also numbered with a value of NG. When the last card is read, NGC is set equal to NG so that NGC becomes the total number of Type-9 cards.

After the Type-9 card costs and spreads are computed, a summing routine for the Type-9 cards sums these costs and adds them to the existing cost and cost spread arrays. The program then moves directly to printout if there is not a code printout. When there is a code printout, it is first necessary to identify and empty all the "basket" WBS items. Basket WBS items are items whose costs

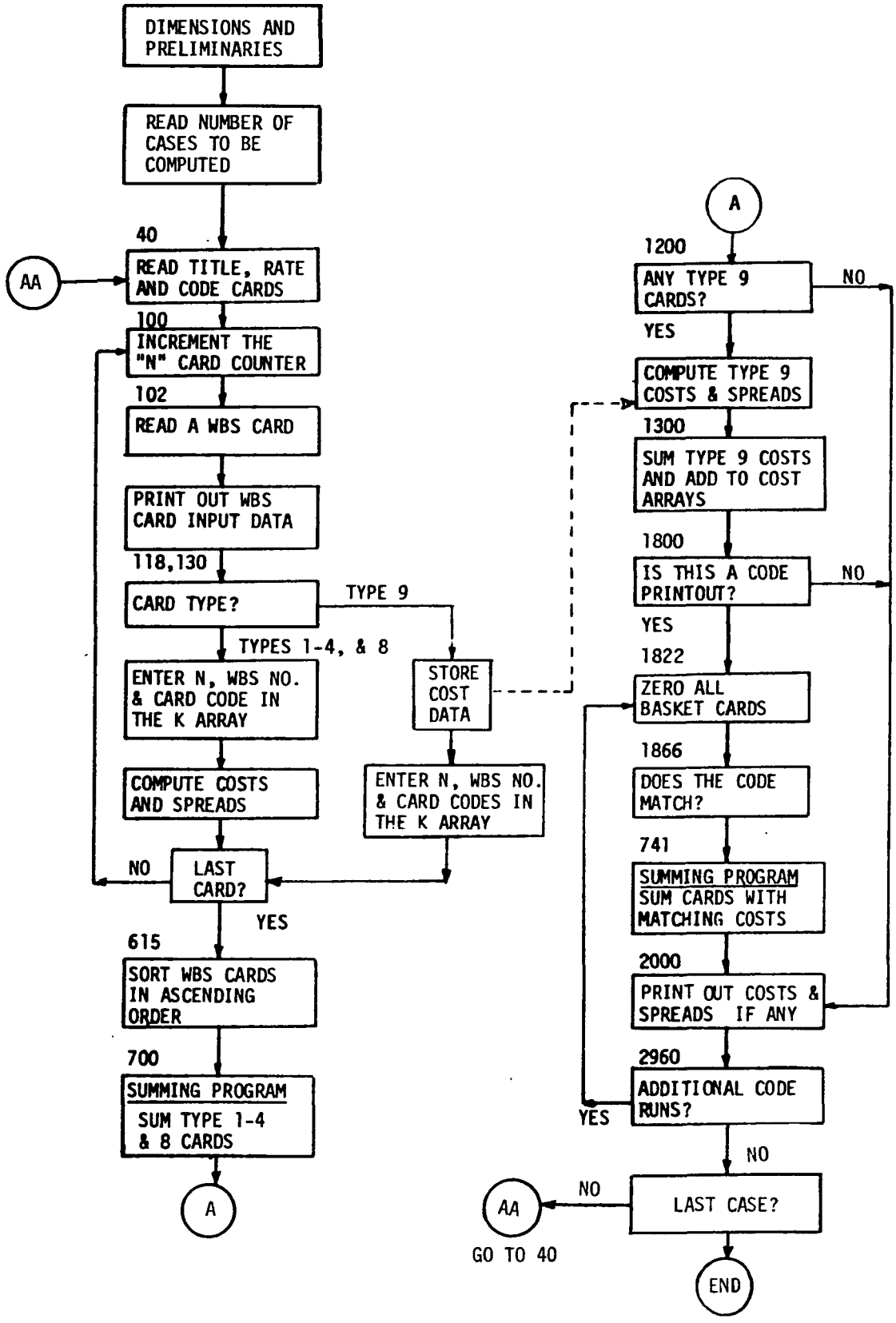


Figure E-18. Condensed Flow Chart

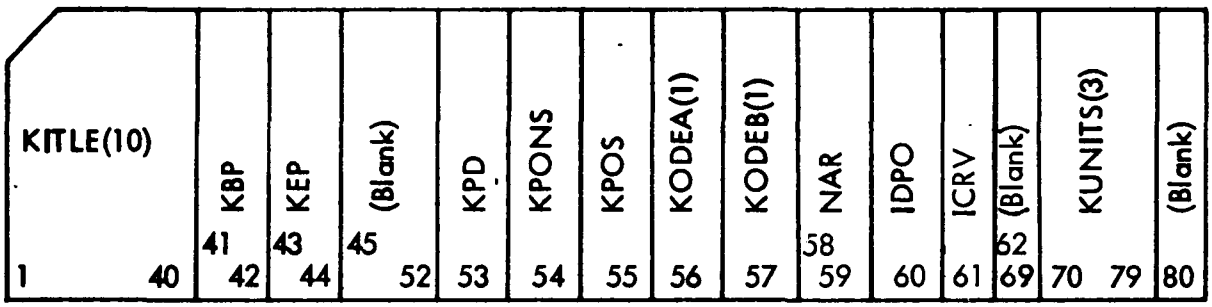
are the sums of other lower-level WBS items. Because only part or none of the lower-level items may have matching codes, it is necessary to set all the basket item costs equal to zero and then resum those items with the appropriate matching codes for printout.

When the basket cards have been zeroed, each WBS item is examined to see if its codes match with the codes required for the printout. The initial summing program is then re-entered and the basket items are refilled with sums of appropriately coded cards. These are subsequently printed out. After each printout the number of printouts is compared with the required number of printouts with respect to spread and no-spread and additional code run requirements, and the routines are repeated as required.

INPUT DATA CARD SYMBOLS

Symbols used in the program in connection with the data cards are described below.

Title Card



Columns	*Symbol*	*Item*
1-40	KITLE	Name of the program
41-42	KBP	Begin period
43-44	KEP	End period
45-52	--	(Not used)
53	KPD	Position of decimal
54	KPONS	Printout level, no spread
55	KPOS	Printout level, spread
56	KODEA(1)	Code A
57	KODEB(1)	Code B
58-59	NAR	Number of additional code runs (up to 99)
60	IDPO	Input data printout
61	ICRV	Variable flag indicating whether graphs are to be produced
62-69	--	(Not used)
70-79	KUNITS	Name of units (dollars, man-months, etc.)
80	--	(Not used)

Code Name Card

1-40	ICODA (I,10)	Name of Code A category to be printed
41-80	ICODB (I,10)	Name of Code B category to be printed

(One Code Name for each code run. I = 1 if initial run is a code run. If additional code runs, I corresponds to I on additional code run cards.)

CRT Plot Title Cards

1-80	NAMX	Card giving label for abscissa (X-axis) of plots
1-80	NAMY	Card giving label for ordinate (Y-axis) of plots
1-80	ITLE	Card giving title for graph heading

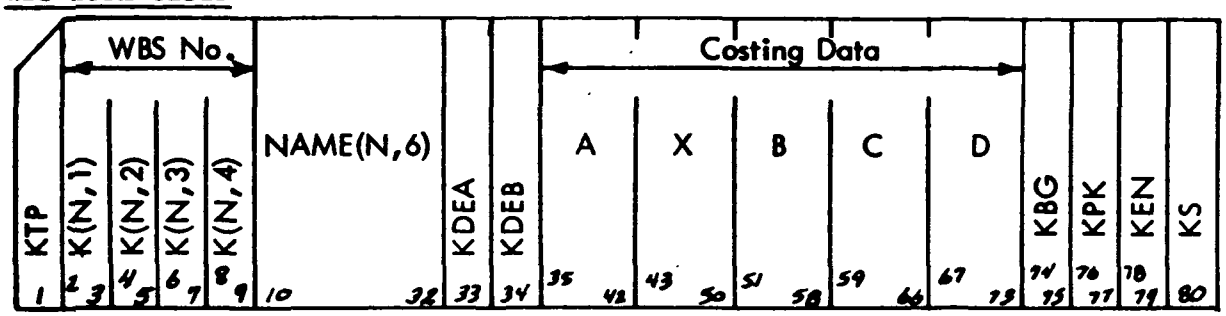
Additional Code Run Cards

1-55	-	(Not used)	
56	KODEA(I)	Code A	where I = 2 to NAR + 1
57	KODEB(I)	Code B	
58-80	-	(Not used)	

Rate Card

1-8	R1	Rate 1
9-16	R2	Rate 2
⋮	⋮	⋮
65-72	R9	Rate 9

WBS Item Cards



Columns	*Symbol*	*Item*	
1	KTP	Card type	
2-3	K(N,1)	Level 1	WBS Number
4-5	K(N,2)	Level 2	
6-7	K(N,3)	Level 3	
8-9	K(N,4)	Level 4	
10-32	NAME(N,6)	WBS item name (6 is required for a storage of 23 letters)	

33	KDEA	Code A
34	KDEB	Code B
35-42	A	Costing Data Note: These are identified as A, B, C, D, E, respectively, in the User Instructions (p. 16)
43-50	X	
51-58	B	
59-66	C	
67-73	D	
74-75	KBG	Begin period
76-77	KPK	Peak period
78-79	KEN	End period
80	KS	Spread option

It should be noted on the WBS Item Cards that the costing data identified in the User Instructions as A, B, C, D, and E are called A, X, B, C, D, respectively, in the source program listing. The exchange of letters came about because the basic CER costing equation (Card Type 1) was initially thought of as Cost = $(AX^B)C+D$, where X was the technical costing parameter such as weight. When the program was completed and the User Instructions were being written, it became apparent that A, X, B, C, D would be confusing as applied to the other card-type equations. Accordingly, it was decided to make the transition and call the costing data entries simply A, B, C, D, E. The basic CER equation could then be though of as Cost = $(AB^C)D+E$.

ARRAY SUBSCRIPTS

Principal data arrays used in the program are identified in Annex A. In general, the N-subscripted arrays are used to identify data associated with individual WBS items and/or cards such as COST(N). L has been used generally to designate spread periods such as in CST(N,L) which is COST(N) spread to L periods. The NG-subscripted arrays are used to store data associated with Type 9 cards as described above.

COST COMPUTATIONS AND TERMS

The principal cost terms used in the program are as follows:

	All WBS Items	Type 9 WBS Items
Total program	COSTT	GOSTT
Total program spread to L periods	CSTT(L)	GSTT(L)
WBS items	COST(N)	COSTG(NG)
WBS items spread to L periods	CST(N,L)	CSTG(NG,L)

Costs are initially computed for each WBS item card in accordance with the applicable card-type equation and using the term CCST. CCST is then transferred to either COST(N) or COST(NG) as the case may be. If spread costs are required, CCST is then used by the same spreading routines regardless of whether the item is a non-Type 9 COST(N) item or a Type 9 COSTG(NG) item. Subsequently, the spread costs are transferred to either CST(N,L) or CSTG(NG,L) as required.

COST SPREADING

The bell-shaped cost spreading curves are based on the Beta function which has often been used for cost distributions (Reference: Shuttle Program, Cost and Schedule Estimates Plan, MSC-03314, 25 June 1971). For this purpose the function can be reduced to the relatively simple equation:

$$CX_T = T^{P-1}(1-T)^{Q-1}$$

where

CX_T is the ordinate value at time, T

T is the proportion of time from 0 to 1.0

P and Q are constants

The shape of the resultant bell-shaped curve is dependent upon the values assigned to the constants, P and Q. As P and Q are increased, the curve becomes more peaked. Lower values of P and Q give flatter curves. If P and Q are equal, the curve is symmetrical. As P is increased greater than Q, the curve is skewed right. As Q is increased greater than P, the curve is skewed left.

The nominally peaked curves selected by Spread Option 2 approximate the peakedness of the standard ogive-type cost curves used by Rockwell Space Division Contracts and Pricing department.

The relatively less and more peaked curves (Spread Options 1 and 3, respectively) were defined by judgment relative to nominal Type 2 curves. In cases where the Beta function has been used for spreading costs with which the writer is familiar, it has not been possible to readily select the peak of the curve at any desired period of time. In order to make this possible, a calculation was made to find the combinations of P and Q values which would place the peak of the curve at proportionate times, T, equal to 0.1, 0.2, 0.3, ... 0.9, and for a degree of peakedness approximating the desired peakedness for each of the Spread Options 1, 2, and 3. These values of P and Q were then tabulated and entered into the SCM program as PA(I,J) and QA(I,J), respectively, at the beginning of the program after the arrays are dimensioned. The I subscript designates the Spread Options 1, 2, or 3. J represents the proportionate times, 0.1, 0.2, 0.3, ... 0.9. An interpolation routine, Step 225, and following is used to find intervening values of P and Q from the PA and QA arrays. This permits the peak to be at the period designated peak (KPK) for spreads with any selected number of periods.

The values of CX(L) are computed at the center of each period designated L; and the total cost (CCST) for the WBS item is distributed proportionably in accordance with CX(L), Steps 234-238. The values of CX(L) are in turn transferred to CST(N,L) (Step 294) starting in the correct period (L) as determined by the relation of KBG, Begin period for the WBS item and KBP, Begin period for the program. The shape of the bell curves used in the program could be changed by changing the values of PA and QA in the PA and QA arrays if desired. Figure E-19 shows relative shapes of the bell-shaped curves.

Similar but simpler routines are used for nonbell-shaped spread options. The increasing portion of the Spread Option 5 curve is based on the equation

$$CX_T = [1-2.718]^{-4.65(T^{2.732})}$$

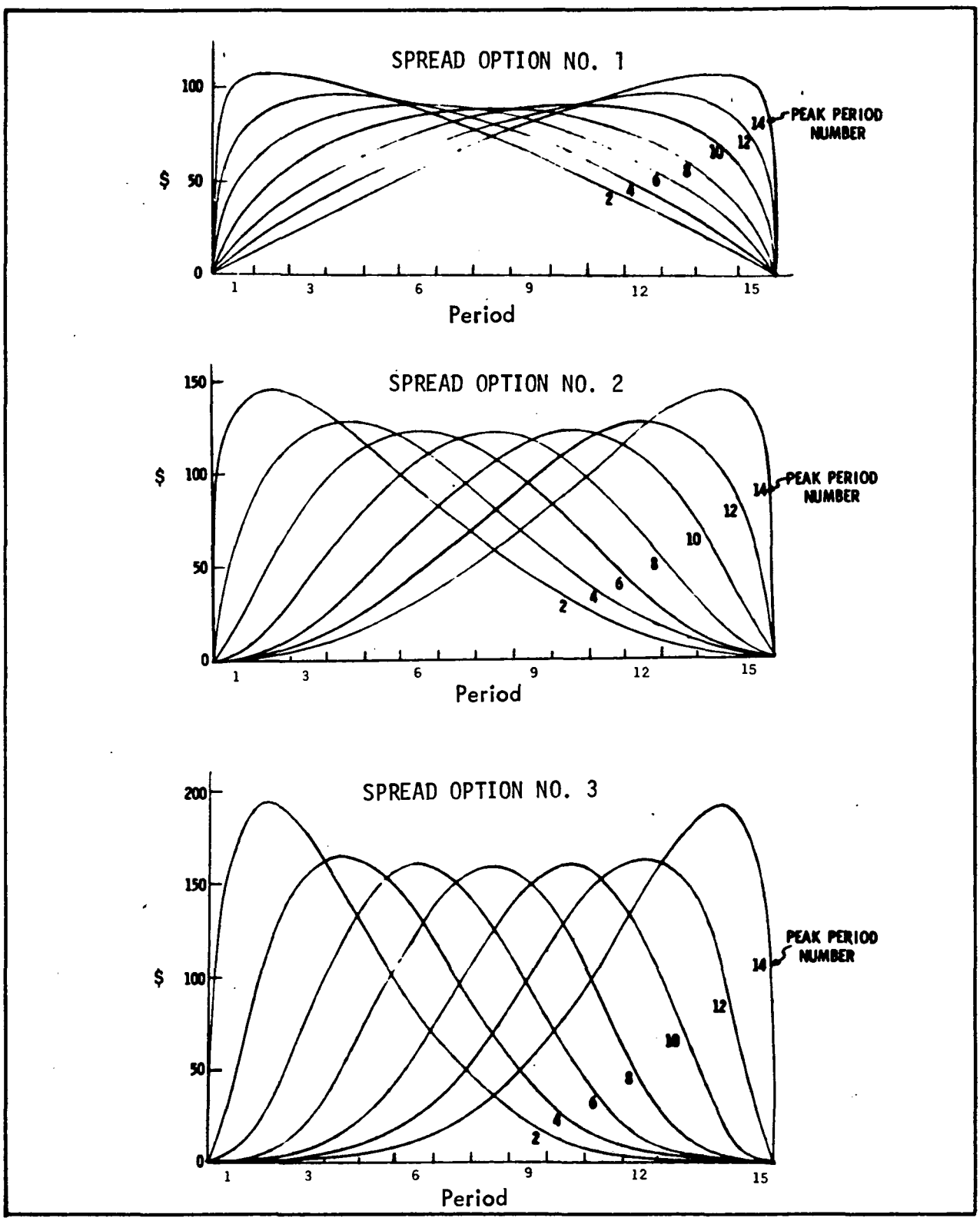


Figure E-19. **Spreading Curve Shapes, Options 1 - 3 (Area under all curves = $1000)**

where

CX = ordinate value
T = proportion of time from 0 to 1.0

Throughout the program, numbers designated L extend from 1 up to the total number of periods in the program (LS) which is equal to KEP-KBP+1 (End period-Begin period plus 1) taken from the title card. At Step 2356 in the printout routines, KBPS(L) is set equal to KBP+L-1. (KBPS(L) then becomes the period number with the first period starting with the number KBP on the title card and is used for printout. For the cathode ray tube (CRT) plots of the spread curves, a floating point variable BPS(L) must be set equal to KBPS(L) to be used as the abscissa of the plots. The ordinate is CSTT(L) for curves of the total program cost, or CST(N,L) for WBS item cost spread curves. A subroutine titled "Graph" has been incorporated in the SCM program deck to give the capability to generate cost spread curves when desired.

K(N,J) ARRAY

The K(N,J) array which is illustrated in Figure E-20 is the principal array used in the operation and control of the program. All the operations in the program which require examining or processing individual WBS card data are controlled by working either up or down the K(N,J) array, i.e., from N = 1 to NC (number of cards) or from N = NC to 1. The values of N and NG are then taken from Columns 5 and 6 of the K(N,J) array to locate data in the other N and NG subscripted arrays. The K(N,J) array also provides a means of keeping track of the values of N, NG and certain other data associated with each WBS item number before and after the WBS numbers are sorted (see Sorting Program).

The first four columns K(N,1), K(N,2), K(N,3) and K(N,4) of the K(N,J) array are the four parts of the WBS numbers. K(N,5) is the initial value of N designated by the N counter for each WBS item card. K(N,6) is the value of NG designated by the NG counter for each Type-9 card. If the WBS item is not a Type-9 item, K(N,6) is zero.* A three-digit number (as described in Figure E-20), which designates whether the item is a basket item or not and the Codes A and B for the item, are contained in K(N,7).

SORTING ROUTINE

The Sorting Routine (Steps 615-670) arranges the WBS numbers in the K(N,J) array in ascending order if they are not in order at the time the WBS cards are read. This is necessary both for the summing programs and the printout routines. When a WBS number in the array is shifted in line position, all the data on its line, K(N,1) through K(N,7), are also shifted so that the initial values of K(N,5), K(N,6) and K(N,7) are retained for identification with each WBS number.

When the cards are read, the line number N in the K(N,J) array (first column of Figure E-20) is the same as the card number N in the column K(N,5). After the sorting is completed the number K(N,5) may no longer correspond to the line number in the array. Therefore, prior to sorting, N alone is used to relate

*It should be noted that after the Type-9 cards are summed, K(N,6) is used for another purpose in the program.

a WBS number in the K(N,J) array to data in the other N subscripted arrays. After sorting, it is necessary to use K(N,5) for this purpose. For example prior to sorting, COST(N) is the cost associated with WBS number K(N,1-4). After sorting, COST[K(N,5)] is used to identify the cost associated with WBS number K(N,1-4). Comparably, K(N,6) is used to identify NG and K(N,7) is used to identify whether the item is a basket item or not and its Codes A and B.

SUMMING ROUTINES

In both the main cost summing routines (Steps 700-1143) and the Type-9 item summing routines (Steps 1300-1772), each WBS number in the K(N,J) array is examined starting at the bottom of the list (largest number) and working up. The level of the item in the tree is determined and the costs are accumulated in accumulators C1, C2, C3 and CS1, CS2, and CS3 until the next level basket item appears, and the accumulated cost is transferred to the basket item. K(N,5) provides the location of the associated cost in the N arrays.

The Type-9 item summing routine is similar except that it works with COSTG(NG) and CSTG(NG,L); K(N,6) is used to tell if the item is a Type-9 item, and as the items are summed, costs are transferred to the COST(N) and CST(N,L) arrays.

CODE PRINTOUTS

After the Type-9 item summing is completed, the question of a code printout is examined at Step 1800. If the next printout is a code printout, KODPO is set to equal 1 to indicate a code printout. K(N,7) is used to determine which items are basket items and costs for them are zeroed. Preparations are then made for resumming the items with appropriate codes. Starting at Step 1840, each line is looked at in the K(N,J) array starting at the bottom line (N = NC) and working up until N = 0. K(N,7) is used to identify the codes A and B for each card. If an item matches the codes for the printout (Steps 1866-1870), or if it is a basket item, K(N,6) is set = 1 and the item is reentered in the main summing routine for summing. At this point, the memory location K(N,6) is used for a new purpose. It was previously used to indicate a Type-9 item, but that is no longer needed. K(N,6) = 1 now indicates the item is to be retained for the code printout; K(N,6) = 0 means it is not to be retained, and this information is used in the printing routine.

PRINTOUT

The printout routines are complicated by the flexibility the program offers to be able to print out spread or no-spread, with and without plots of spread costs, desired codes, and down to selected levels in the WBS tree. The same basic printout routine is used over again for each printout and several items are thus needed to indicate the kind of printout required and to control the operation. KDSET set to 1 or 0 tells whether the divisions to set the decimal have been previously performed. KSP set to 1 or 0 means spread printout or not. NPRINT is used to count the printouts and match with NAR (number of additional runs) to see if additional printouts are required. A line counter, LC, is also used to provide wider margins at the top and bottom of pages so that printed pages can be reproduced directly for use in an 8-1/2 inches by 11 inches

Line (N)	Columns (J)						
	1	2	3	4	5	6**	7
1	01	00	00	00	N	NG	*
2	01	01	00	00	N	NG	*
3	01	01	01	00	N	NG	*
4	01	01	01	01	N	NG	
5	01	01	01	03	N	NG	
6	01	01	02	00	N	NG	
7	01	01	02	01	N	NG	
⋮		⋮			⋮	⋮	

WBS Item Number

*K(N,7) is a three-digit number:

- First digit is 0 or 1. A 1 indicates the WBS item is a "basket item" (i.e., the sum of other WBS items). A 0 indicates a non-basket item.
- Second digit is the Code A for the item.
- Third digit is the Code B for the item.

EXAMPLE: "031" means a non-basket card with A, B Codes = 3, 1, respectively.

**K(N,6) initially is the value of NG for each WBS item. After Card 9 summing routines at Steps 1868-1890, it is redefined so that K(N,6) = 1 means a WBS item is to be retained for code printout; K(N,6) = 0, means it is not.

Figure E-20. K(N,J) Array

report with adequate margins. LEV is set equal to 1, 2, 3, or 4 to indicate to what level of the WBS tree the printout is to be made. KSPD is used in conjunction with the line counter.

After the program title, headings and program costs are printed, a do-loop, N = 1 to NC (Steps 2400 to 2930), is used to examine each WBS item for printing and then print it if it meets the requirement.

If the printout is a code printout, only the items with codes matching the requirement and basket cards are retained for printout. This is indicated by a K(N,6) = 1 (Step 2401). Basket cards are further examined and rejected if their costs are zero. When their costs are zero, it indicates that there were no lower-level items under the items with the required matching codes. The WBS numbers are also examined (Step 2410 and following) to determine the level of each item in the WBS tree. This is necessary because line spacing and indentation are different for the different levels and the printout may be only to a selected level of the tree.

Each time through the printout routine, the spread printout (if required) is printed first. If a spread printout is required, the program first tests the variable ICRV to determine whether spread plots are also required. If so, the program calls the Subroutine Graph to produce the plots. The program then continues through the spread printout routine. When this is complete, the program returns from Step 2940 back to Step 2205 to see if a no-spread printout is required. Subsequently, the program examines NPRINT and NAR to see if all the printout runs are complete or if more printouts are due.

DATA INPUT ERRORS

At several points in the program, arrangements have been made to print out an error message in the input data when such an error occurs and it is possible to detect. These arrangements will not catch most errors, but will identify certain unacceptable combinations of input data--for example, a non-existing card-type number (Step 133) or a non-existing spread option number (Step 208). In the former case the cost of the item is not computed but the program continues. In the second case, Spread Option 2 is substituted and the program continues. Zeros at unacceptable locations in the WBS numbers are detected and trigger error notations at several places in the summing routines. Two identical WBS numbers will be detected in the sorting routine and a printout notation made. In the cases of errors in the WBS numbers, the program goes on but the numbering errors result in errors in the summing routines, so that the totals are usually wrong.

Printouts stating that there are errors in input data should be carefully watched for because the final results will also be in error. In each case the program is set to continue so that additional similar input errors (if any) may be detected, and so that some results may be obtained. An error on one input card may have only minor effect on the total program, or it may have major effect such as upsetting the summing routines or code logic. Most errors in input data cannot be detected but simply result in comparably erroneous outputs. Others may simply bring the program to a halt due to some condition the computer cannot handle.

PROGRAM DIMENSIONS AND CHANGING PROGRAM CAPACITY

The number of WBS Item Cards which can be handled by the program is limited by the numerical value of N in the dimension statement for the N arrays, which is the first statement of the program. Similarly, the number of Type 9 cards is limited by the value of NG in the dimension statement for the NG arrays, which is the second statement of the program. The size of N and NG significantly affect computer memory set aside to handle the program. The dimensions can be changed so that when using the program one should examine the size of N and NG in the first two statements of the program, i.e., N in K(N,L) and the other arrays of the first statement, and NG in AG(NG) and the other arrays in the second statement of the program.

The capacity of the program in terms of maximum number of WBS Item Cards and maximum number of Type 9 cards can be changed by changing N and NG in the first two statements. No other changes are required. For example, to change N, change the numerical value of N in K(N,7), CST(N,L), NAME(N,6), COST(N), and KT(N,4). To change NG, change the numerical value of NG in all the arrays, AG(NG), KX(NG)..... KSG(NG) and CSTG(NG,L) in the second statement of the program. In the listing of Annex C, N = 1000; NG = 25; L = 24.

If it is desired to increase the number of spread periods from the current limitation of 24, additional changes would be required beyond the dimensions. The dimension changes would require changing the value of L in all the arrays in the third statement of the program, and in CST(N,L) in the first statement and CSTG(N,L) in the second statement. In addition, the printout routine would need to be changed to allow for additional lines of period numbers which are printed in parentheses in the headings. Statements 2362 and 4000 to 4005, 4005 to 4020, and 4020 to 5000, provide for printout of the 1st, 2nd, and 3rd lines, respectively, of period numbers in parentheses in the spread printout heading. These would require modification and extension for more lines if the number of periods were increased. The line counter should be adjusted accordingly in the WBS item printout routines. Other changes should not be required.

ANNEX A

LIST OF PROGRAM SYMBOLS

ANNEX A

LIST OF PROGRAM SYMBOLS

This annex contains a listing of the symbols used in the program with the exception of dummy variables or subscripts whose definition may be obtained by examination of the listing. The first part of the annex identifies array symbols. These are followed by an alphabetical listing of non-array symbols. If a symbol is not found in the alphabetical section, examine the array symbols.

N Arrays	The N arrays are defined as arrays with an N subscript which are used to store data related to individual WBS items.
K(N,J)	See Figure E-20 in appendix text
K(N,1-4)	WBS number
K(N,5)	N card counter
K(N,6)	NG card counter prior to Steps 1868-1890. It is then redefined: K(N,6)= 1 retain item for code printout K(N,6)= 0 reject item for code printout
K(N,7)	A three-digit number designating basket cards and Codes A and B; see Figure E-20.
NAME(N,J)	Name of each WBS item (J = 6, required for storage of 23 letters; see WBS Item Card symbols.)
COST(N)	Cost of each WBS item
CST(N,L)	Cost spread for each WBS item.
KT(N,J)	Test array for holding data from the K(N,J) array in the sorting routine.
KT(N,1)	= K(N,1-4) = WBS number
KT(N,2)	= K(N,5) = N
KT(N,3)	= K(N,6) = NG
KT(N,4)	= K(N,7) defined above
NG Arrays	The NG arrays are defined as arrays with an NG subscript used to store data associated with Type 9 WBS items.
AG(NG)	= A
KX(NG)	= X
KB(NG)	= B
KC(NG)	= C
KD(NG)	= D

Cost data from Type 9 WBS Item Cards. A is a ratio. X,B,C,D are another WBS item number.

COSTG(NG)	Cost of each Type 9 WBS item
CSTG(NG,L)	Cost spread for each Type 9 WBS item

NG Arrays (Continued)

KBGG(NG)	= KBG	Cost spreading data for each Type 9 card
KPKG(NG)	= KPK	
KENG(NG)	= KEN	
KSG(NG)	= KS	

Rate Array

R(I)	This array stores rates from the Rate Card

Cost Spreading Arrays (L = period number)

CC(L)	Repository for cost spreads for each WBS item prior to transfer to COST(N,L) or COSTG(NG,L)
CX(L)	Array used in calculation of the bell-shaped cost spreads (Spread Options 1, 2 and 3)
TINC(L)	Array used in calculation of Option 5 cost spreads
CSTT(L)	Cost spread for total program costs
GSTT(L)	Cost spread for program total of Type 9 card costs
CS1(L), CS2(L), CS3(L)	Cost accumulators used in summing cost spreads in the summing programs at Levels 2, 3, and 4, respectively
KBPS(L)	Period numbers where KBPS(1) equals the number KBP on the Title Card. See last paragraph under heading "Cost Spreading."
BPS(L)	Same as KBPS(L) in floating point form; used for X-axis of graphs.
PA(I,J) and QA(I,J)	These store values of P and Q used in bell-shaped (Beta curve) cost spreading formulas (I = 1,3) (J = 1,9)

Alphabetical List

A, B, C, D	Costing data; see WBS Item Card symbols
C1, C2, C3	Cost accumulators used in summing costs in the cost arrays at Levels 2, 3, and 4, respectively (Corresponding cost spread accumulators are CS1(L), CS2(L) and CS3(L); see L arrays above.
Amount	Cost term used in computing Options 4 and 5 cost spreads on Type 4 cards
CCST	Cost of WBS element, prior to entry in COST(N) array
COSTT	Total program costs

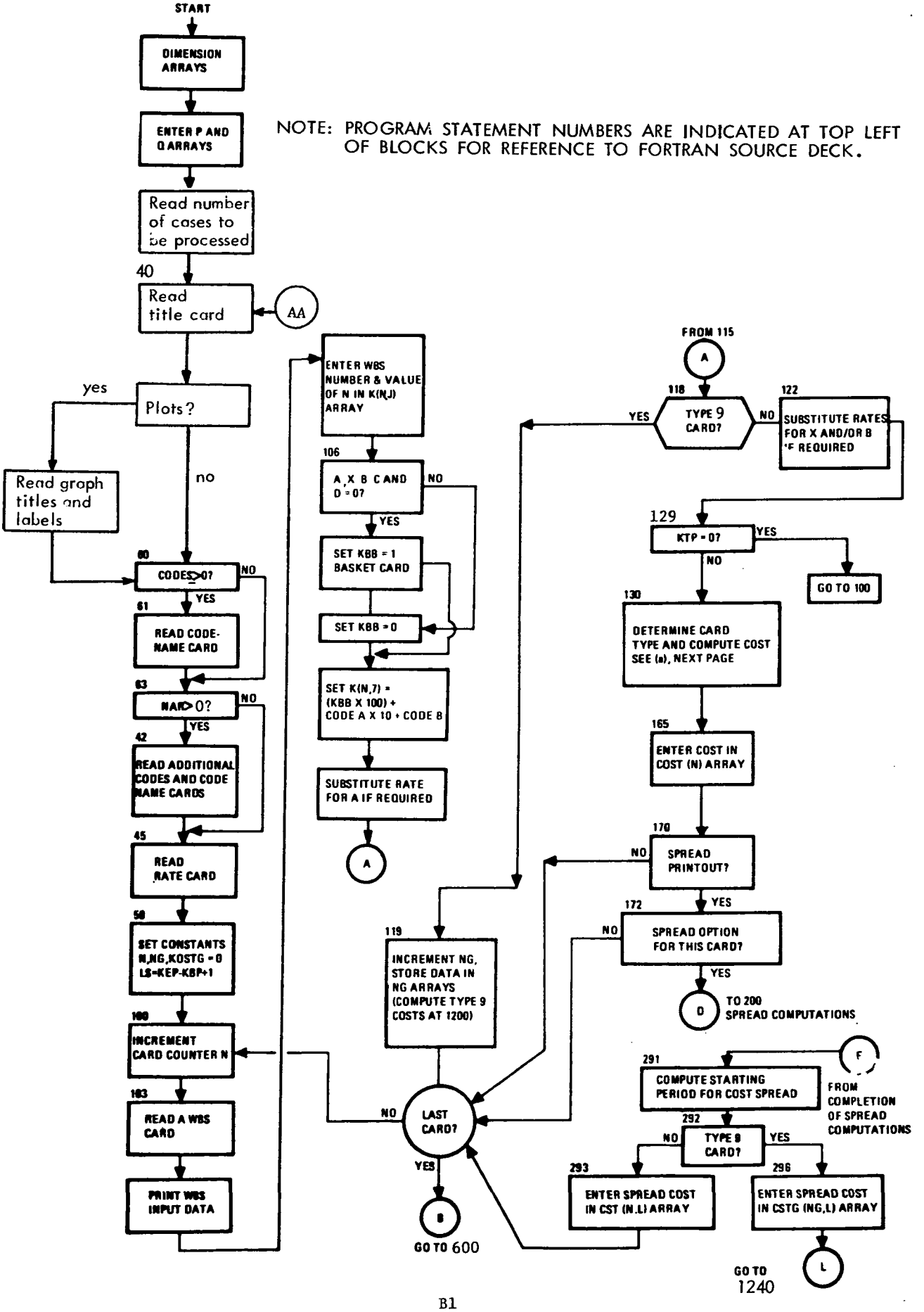
DIFF	Difference
DIFFP	Difference in P
DIFFQ	Difference in Q
	Terms used in interpolating values of P and Q from PA and QA arrays
FRACT	Fraction of time equal to one ÷ no. of periods in spreading calculations
FLAT or IFLAT	Number of periods in flat portion of Option 5 spread curve
GOSTT	Total costs for all Type 9 cards
GRAPH	Subroutine added to the basic program to print data in X-Y CRT format
II	Used as subscript to KODEA(II) and KODEB(II) to identify codes on additional code run cards; see Steps 1820, 1866 and 1868.
ICASE	Dummy variable used to count individual cases in a multiple case run.
ICODA(I) ICODB(I)	Code names; see Code Name Card data input
ICRV	Input variable indicating whether or not graphs are to be produced; see Title Card
IDPO	Input data printout; see Title Card
INC or FINC	Number of periods in increasing portion of Option 5 cost spread curve
ITLE	Title for graphs
K1 K2 K3 K4	Terms designating WBS numbers for prior cards at Levels 1, 2, 3, and 4, respectively in the cost summing programs
KBB	Term used to indicate whether WBS item is a basket item. KBB = 1 it is; 0 it is not.
KBG	Begin spread; see WBS Item Card
KBP	Begin Period; see Title Card
KDEA KDEB	Code numbers A and B on WBS Item Cards
KDSET	Decimal set. KDSET = 1 means divisions to set decimal have been completed previously; 0 means they have not.
KEN	End of spread; see Title Card
KEP	End Period; see Title Card
KH1 KH2 KH3 KH4	Terms for holding KT(N,J) data during sorting routine

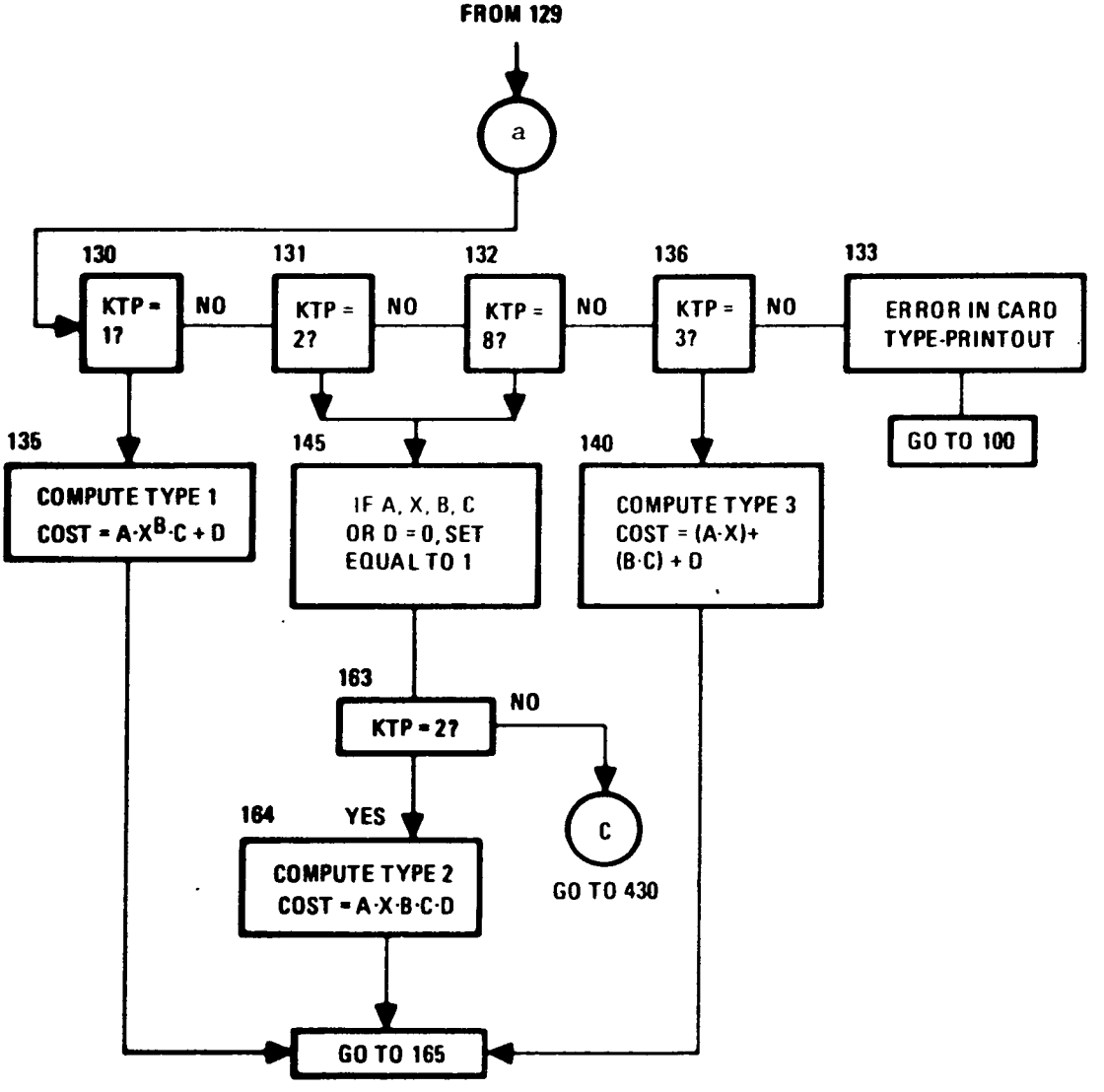
KODEA(I) KODEB(I)	Code Numbers A and B on Title and Additional Code Run Cards; see Input Data Symbols
KODPO	Code printout. KODPO = 1 means code printout. KODPO = 0 means no code printout. Used when going through summing, printing and code matching routines.
KOSTG	Term used to identify whether calculations are for Type 9 or non-Type 9 cards. KOSTG = 0 Non-Type 9 cards KOSTG = 1 Type 9 cards
KP	Term used to retain value of N in sorting routine when it is necessary to start shifting WBS numbers in line position.
KPD	Position of decimal; see Title Card
KPK	Peak of spread; see WBS Item Card
KPOS	Printout level spread; see Title Card
KPONS	Printout level no-spread; see Title Card
KS	Spread Option; see WBS Item Card
KSP	Term used to identify whether the printout operations require printout of cost spreading data or not. KSP = 0 No spread printout KSP = 1 Printout cost spread
KSPD	Spread. A term used in conjunction with the line counter (LC) to allow enough lines for printing of spread costs for each item. KSPD = 2 up to 8 spread periods KSPD = 3 9-16 spread periods KSPD = 4 17-24 spread periods
KTP	Card type; see WBS Item Card
KUNITS	Units program is working in dollars, man-months, etc. See Title Card symbols.
LC	Line counter. Counts lines during printout to provide wider margins.
LENGTH	Number of periods in cost spread for a WBS item.
LEV = 1 LEV = 2 LEV = 3 LEV = 4	Terms designating WBS level to be printed out. LEV = 1, print Level 1 LEV = 2, print Levels 1 and 2 etc.
LS	Length of spread (number of periods) for total program. Defined as LS = KEP - KBP + 1 following Step 52.

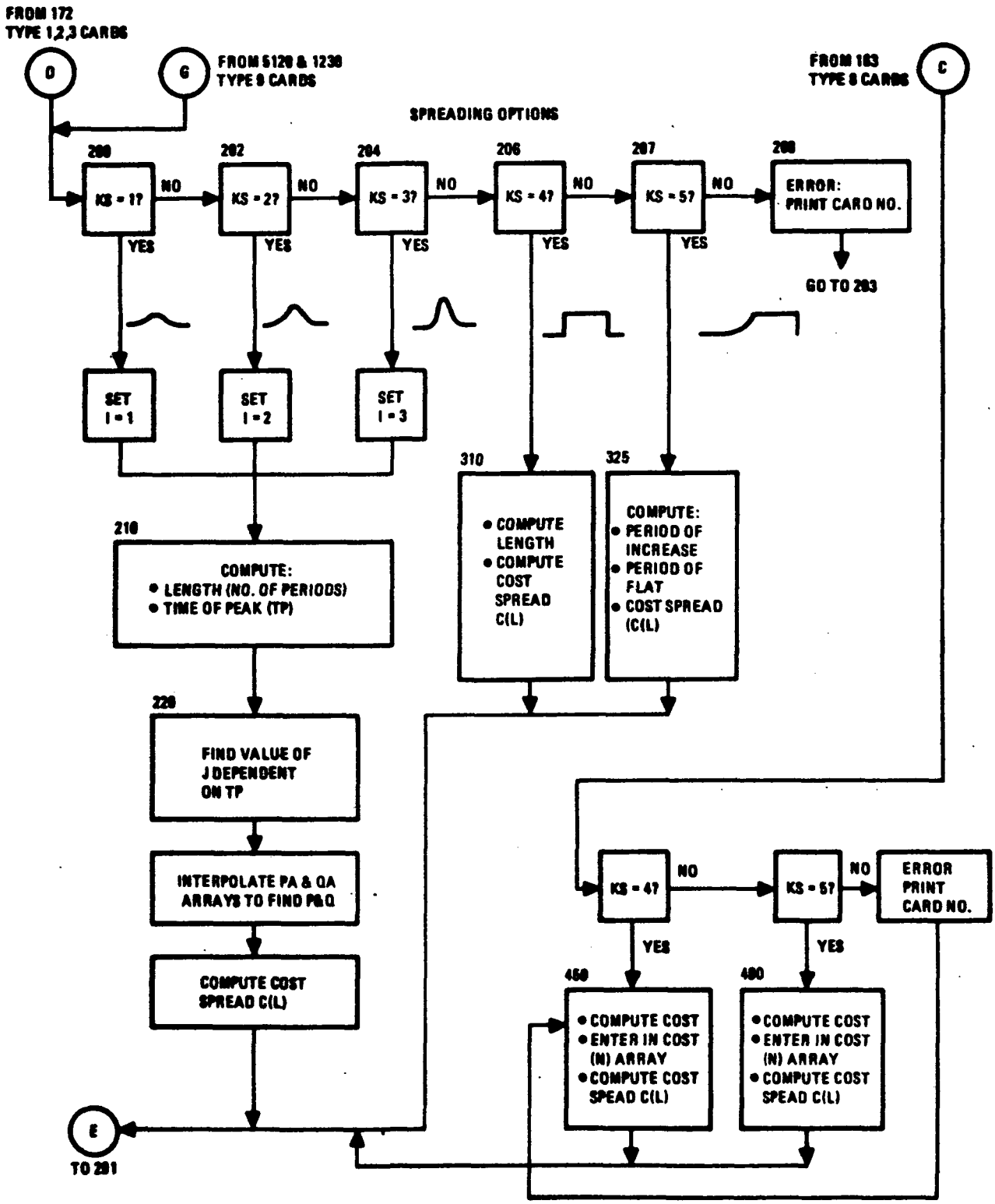
N	Subscript designating WBS Card number or K(N,J) line number
NAMX NAMY	Labels for X and Y axes of graphs
NAR	Number of Additional Code Runs; see Title Card
NC	Number of WBS Item Cards
NCASE	Number of individual cases to be processed in a single run
NG	Subscript designating Type 9 WBS Card number
NGC	Number of Type 9 cards
NP	Subscript, equals K(N,5)
NPRINT	A counter which counts the number of printouts and is then compared with NAR to see if additional printouts are required
P Q	Terms used in bell-shaped (Options 1, 2, 3) cost spreading formulas; see Cost Spreading.
R1, R2 . . .	Rates entered on Rate Card
ST	Starting period for cost spread
SUM	Term used in bell-shaped spreading curve formulas and in Type 5 spread formulas
TP	Time of Peak in spread curve calculation
X	Costing data; see WBS Item Card Data.

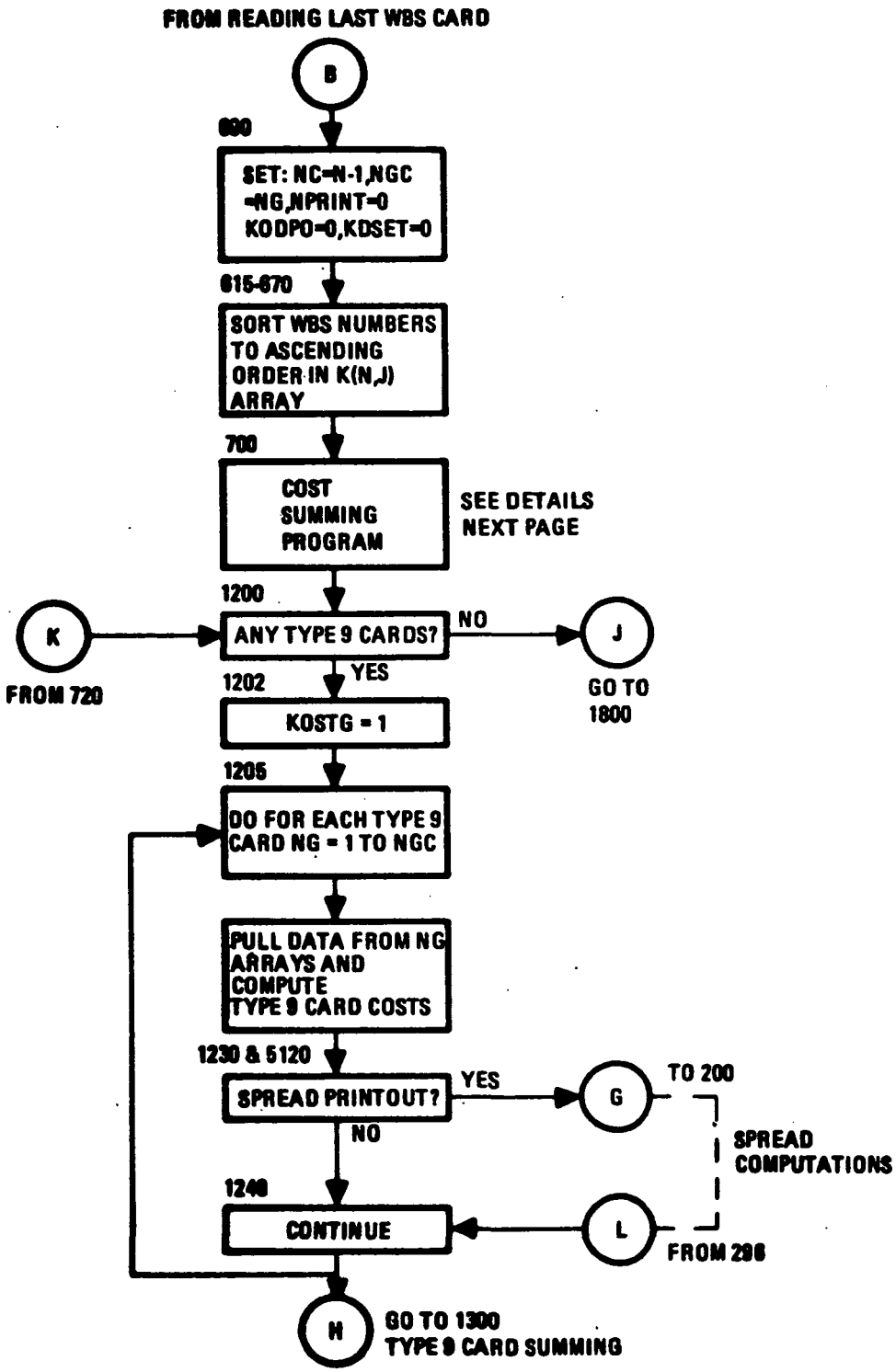
ANNEX B

PROGRAM FLOW CHART

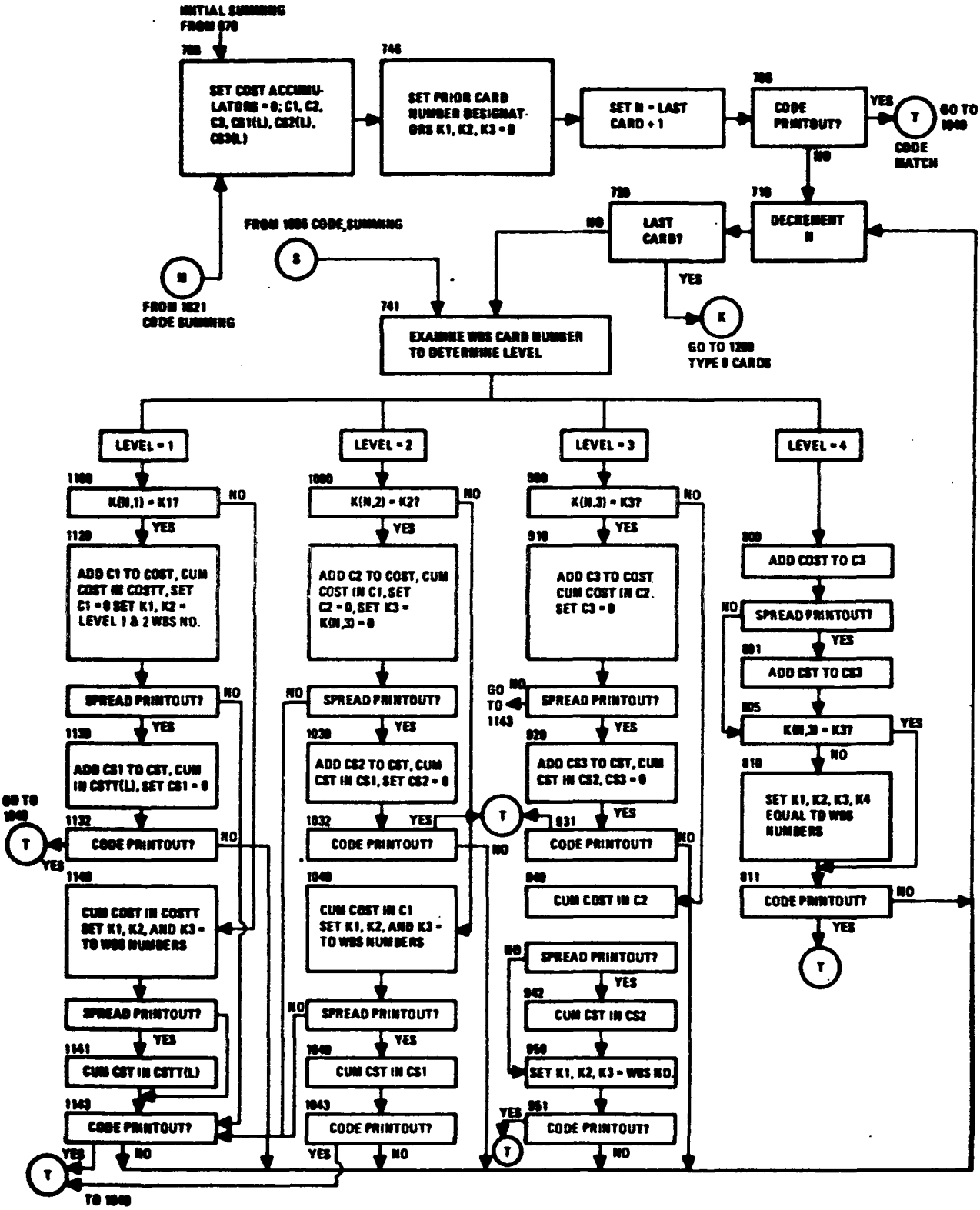

START
DIMENSION ARRAYS
ENTER P AND Q ARRAYS
Read number of cases to be processed
40
Read title card
AA
yes
Plots?
no
Read graph titles and labels
60
CODES>0?
NO
YES
61
READ CODE-NAME CARD
63
NAR>0?
NO
YES
42
READ ADDITIONAL CODES AND CODE NAME CARDS
45
READ RATE CARD
50
SET CONSTANTS N,NG,KOSTG = 0 LS=KEP-KBP+1
100
INCREMENT CARD COUNTER N
103
READ A WBS CARD
PRINT WBS INPUT DATA
ENTER WBS NUMBER & VALUE OF N IN K(N,J) ARRAY
106
A,X B C AND D = 0?
NO
YES
SET K88 = 1 BASKET CARD
SET K88 = 0
SET K(N,7) = (K88 X 100) + CODE A X 10 + CODE B
SUBSTITUTE RATE FOR A IF REQUIRED
A
NOTE: PROGRAM STATEMENT NUMBERS ARE INDICATED AT TOP LEFT OF BLOCKS FOR REFERENCE TO FORTRAN SOURCE DECK.
FROM 115
A
118
TYPE 9 CARD?
YES
NO
122
SUBSTITUTE RATES FOR X AND/OR B IF REQUIRED
129
KTP = 0?
YES
NO
GO TO 100
130
DETERMINE CARD TYPE AND COMPUTE COST SEE (a), NEXT PAGE
165
ENTER COST IN COST (N) ARRAY
170
SPREAD PRINTOUT?
NO
YES
172
SPREAD OPTION FOR THIS CARD?
NO
YES
D
TO 200 SPREAD COMPUTATIONS
119
INCREMENT NG, STORE DATA IN NG ARRAYS (COMPUTE TYPE 9 COSTS AT 1200)
LAST CARD?
NO
YES
B
GO TO 600
F
FROM COMPLETION OF SPREAD COMPUTATIONS
291
COMPUTE STARTING PERIOD FOR COST SPREAD
292
TYPE 8 CARD?
NO
YES
293
ENTER SPREAD COST IN CST (N,L) ARRAY
296
ENTER SPREAD COST IN CSTG (NG,L) ARRAY
L
GO TO 1240

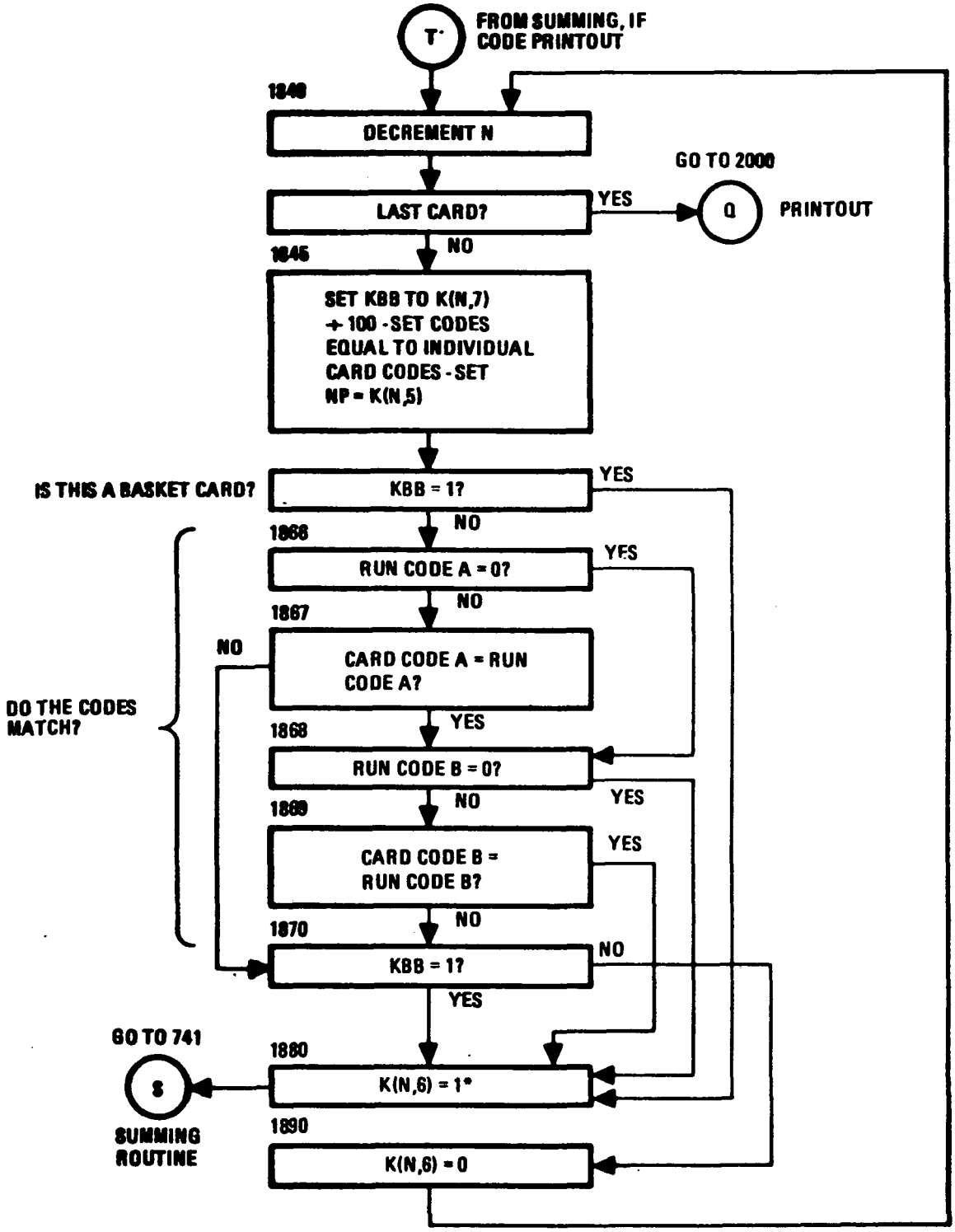

FROM 129
a
130
KTP = 1?
NO
131
KTP = 2?
NO
132
KTP = 8?
NO
136
KTP = 3?
NO
133
ERROR IN CARD TYPE-PRINTOUT
GO TO 100
135
COMPUTE TYPE 1
COST = A·X^B·C + D
145
IF A, X, B, C OR D = 0, SET EQUAL TO 1
140
COMPUTE TYPE 3
COST = (A·X)+ (B·C) + D
163
KTP = 2?
NO
164
YES
COMPUTE TYPE 2
COST = A·X·B·C·D
C
GO TO 430
GO TO 165


FROM 172
TYPE 1,2,3 CARDS
D
G
FROM 5120 & 1230
TYPE 9 CARDS
FROM 183
TYPE 8 CARDS
C
SPREADING OPTIONS
200
KS = 1?
NO
YES
202
KS = 2?
NO
YES
204
KS = 3?
NO
YES
206
KS = 4?
NO
YES
207
KS = 5?
NO
YES
208
ERROR:
PRINT CARD NO.
GO TO 203
SET
I = 1
SET
I = 2
SET
I = 3
210
COMPUTE:
• LENGTH (NO. OF PERIODS)
• TIME OF PEAK (TP)
310
• COMPUTE
LENGTH
• COMPUTE
COST
SPREAD
C(L)
325
COMPUTE:
• PERIOD OF
INCREASE
• PERIOD OF
FLAT
• COST SPREAD
(C(L)
220
FIND VALUE OF
J DEPENDENT
ON TP
INTERPOLATE PA & QA
ARRAYS TO FIND P&Q
COMPUTE COST
SPREAD C(L)
KS = 4?
NO
KS = 5?
NO
ERROR
PRINT
CARD NO.
YES
YES
450
• COMPUTE COST
• ENTER IN COST
(N) ARRAY
• COMPUTE COST
SPEAD C(L)
490
• COMPUTE COST
• ENTER IN COST
(N) ARRAY
• COMPUTE COST
SPEAD C(L)
E
TO 291


FROM READING LAST WBS CARD
B
600
SET: NC=N-1,NGC =NG,NPRINT=0 KODPO=0,KDSET=0
615-670
SORT WBS NUMBERS TO ASCENDING ORDER IN K(N,J) ARRAY
700
COST SUMMING PROGRAM
SEE DETAILS NEXT PAGE
1200
K
FROM 720
ANY TYPE 9 CARDS?
NO
J
GO TO 1800
YES
1202
KOSTG = 1
1205
DO FOR EACH TYPE 9 CARD NG = 1 TO NGC
PULL DATA FROM NG ARRAYS AND COMPUTE TYPE 9 CARD COSTS
1230 & 5120
SPREAD PRINTOUT?
YES
G
TO 200
SPREAD COMPUTATIONS
NO
1240
CONTINUE
L
FROM 298
H
GO TO 1300 TYPE 9 CARD SUMMING

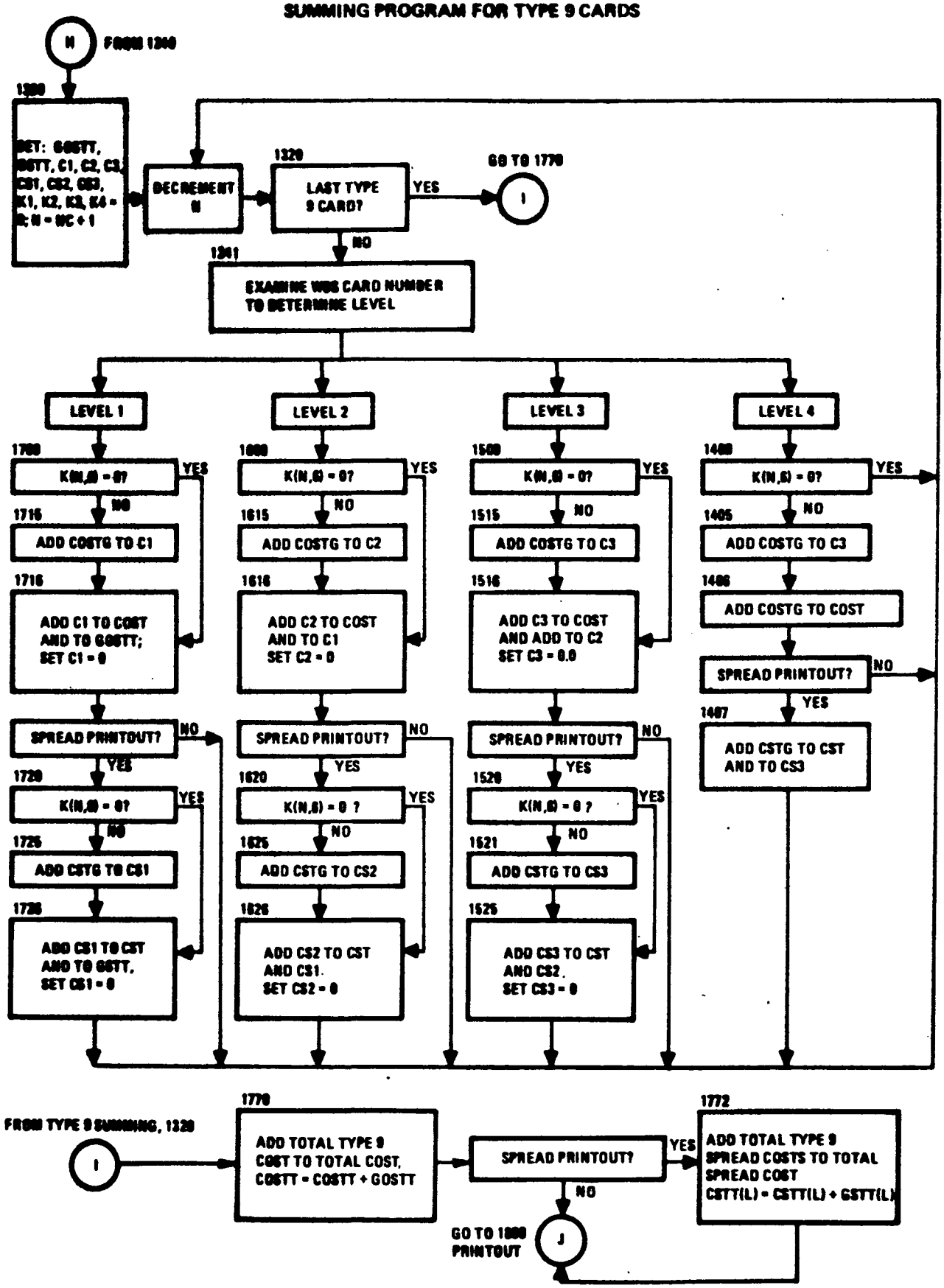
DETAILS OF SUMMING PROGRAM

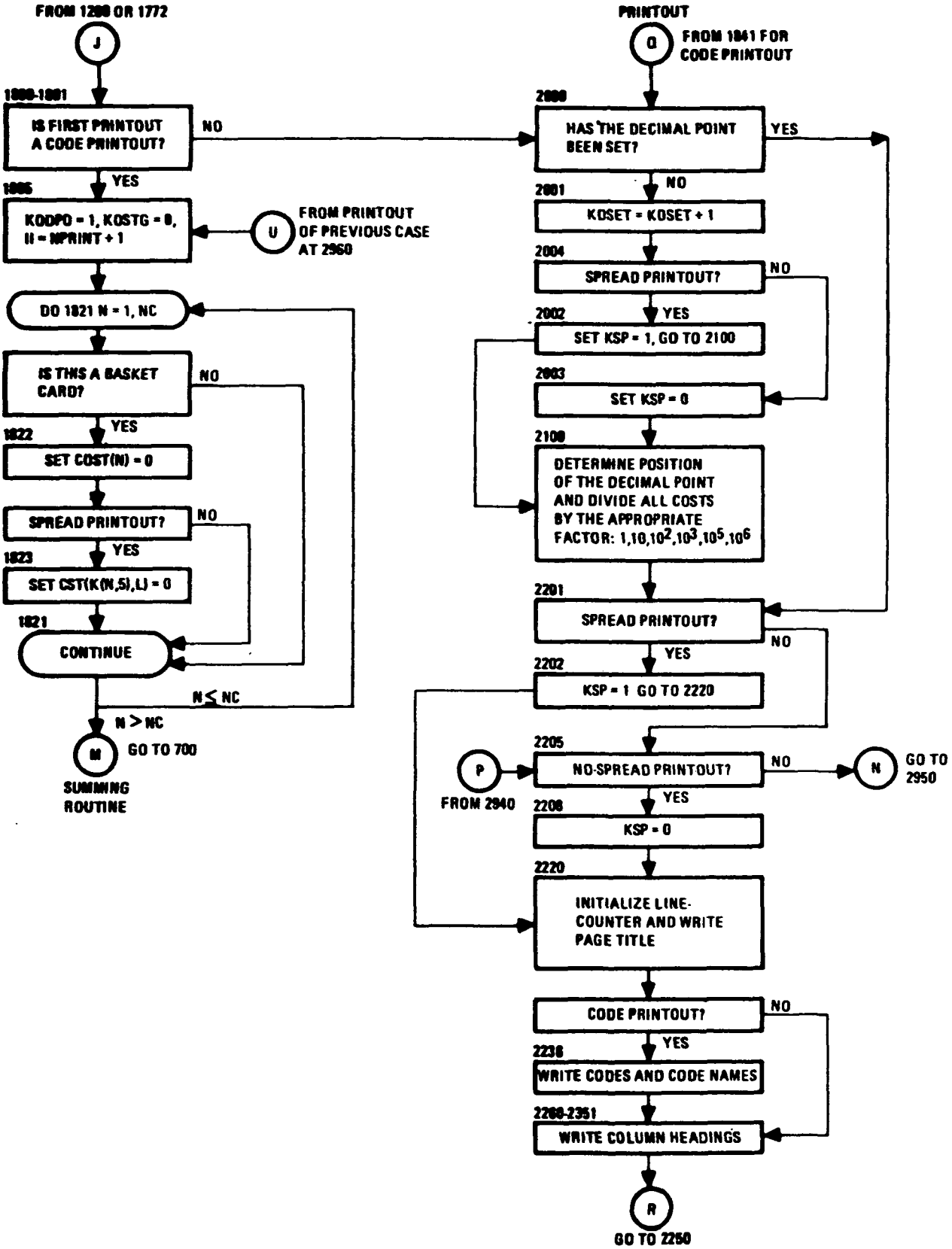


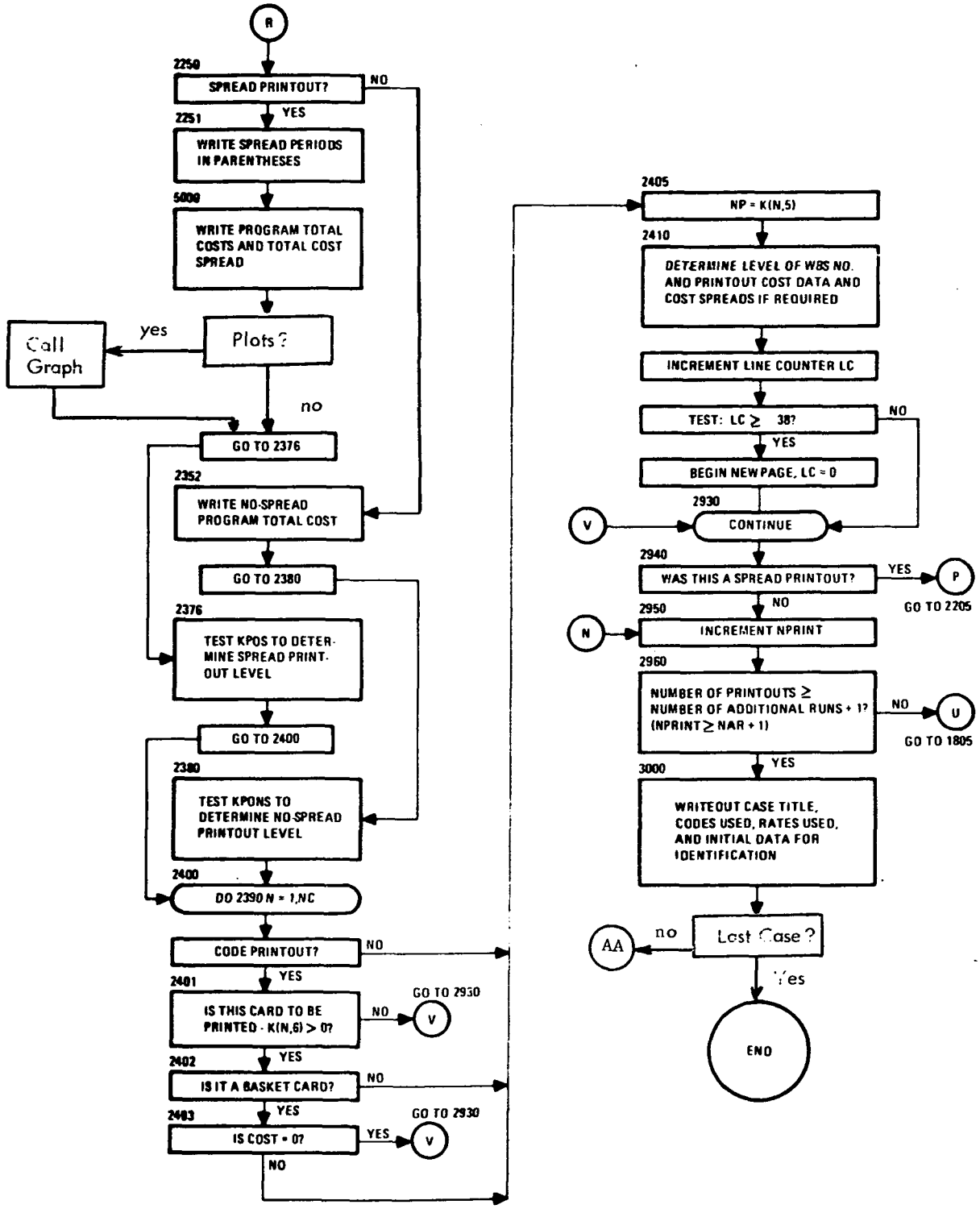


*K(N,6) = 1 AT STEP 1800 MEANS THE WBS ITEM IS TO BE RETAINED FOR THE SUMMING ROUTINE. K(N,6) = 0 MEANS IT IS NOT RETAINED.

SUMMING PROGRAM FOR TYPE 9 CARDS




FROM 1200 OR 1772
J
1800-1801
IS FIRST PRINTOUT A CODE PRINTOUT?
NO
YES
1805
KODPO = 1, KOSTG = 0, II = NPRINT + 1
U
FROM PRINTOUT OF PREVIOUS CASE AT 2960
DO 1821 N = 1, NC
IS THIS A BASKET CARD?
NO
YES
1822
SET COST(N) = 0
SPREAD PRINTOUT?
NO
YES
1823
SET CST(K(N,5),L) = 0
1821
CONTINUE
N ≤ NC
N > NC
M
GO TO 700
SUMMING ROUTINE
PRINTOUT
Q
FROM 1841 FOR CODE PRINTOUT
2000
HAS THE DECIMAL POINT BEEN SET?
YES
NO
2001
KOSET = KOSET + 1
2004
SPREAD PRINTOUT?
NO
YES
2002
SET KSP = 1, GO TO 2100
2003
SET KSP = 0
2100
DETERMINE POSITION OF THE DECIMAL POINT AND DIVIDE ALL COSTS BY THE APPROPRIATE FACTOR: 1,10,10^2,10^3,10^5,10^6
2201
SPREAD PRINTOUT?
NO
YES
2202
KSP = 1 GO TO 2220
2205
NO-SPREAD PRINTOUT?
NO
N
GO TO 2950
YES
P
FROM 2940
2208
KSP = 0
2220
INITIALIZE LINE-COUNTER AND WRITE PAGE TITLE
CODE PRINTOUT?
NO
YES
2238
WRITE CODES AND CODE NAMES
2260-2351
WRITE COLUMN HEADINGS
R
GO TO 2250


R
2250
SPREAD PRINTOUT?
NO
YES
2251
WRITE SPREAD PERIODS IN PARENTHESES
5000
WRITE PROGRAM TOTAL COSTS AND TOTAL COST SPREAD
Call Graph
yes
Plots?
no
GO TO 2376
2352
WRITE NO-SPREAD PROGRAM TOTAL COST
GO TO 2380
2376
TEST KPOS TO DETERMINE SPREAD PRINTOUT LEVEL
GO TO 2400
2380
TEST KPONS TO DETERMINE NO-SPREAD PRINTOUT LEVEL
2400
DO 2390 N = 1,NC
CODE PRINTOUT?
NO
YES
2401
IS THIS CARD TO BE PRINTED - K(N,6) > 0?
NO
GO TO 2930
V
YES
2402
IS IT A BASKET CARD?
NO
YES
2403
IS COST = 0?
YES
GO TO 2930
V
NO
2405
NP = K(N,5)
2410
DETERMINE LEVEL OF WBS NO. AND PRINTOUT COST DATA AND COST SPREADS IF REQUIRED
INCREMENT LINE COUNTER LC
TEST: LC ≥ 38?
NO
YES
BEGIN NEW PAGE, LC = 0
2930
V
CONTINUE
2940
WAS THIS A SPREAD PRINTOUT?
YES
P
GO TO 2205
NO
2950
N
INCREMENT NPRINT
2960
NUMBER OF PRINTOUTS ≥ NUMBER OF ADDITIONAL RUNS + 1? (NPRINT ≥ NAR + 1)
NO
U
GO TO 1805
YES
3000
WRITEOUT CASE TITLE, CODES USED, RATES USED, AND INITIAL DATA FOR IDENTIFICATION
AA
no
Last Case?
Yes
END

ANNEX C

SOURCE PROGRAM LISTING*

*Program listing in format for IBM machines.

```
C     ******************************************
C
C                          SCM
C
C     ******************************************
C
ISN 0002      DIMENSION K(1000,7),CST(1000,24),NAME(1000,6),COST(1000),
             *KT(1000,4)
ISN 0003      DIMENSION AG(25),KX(25),KB(25),KC(25),KD(25),COSTG(25),KBGG(25),
             *KPKG(25),KENG(25),KSG(25),CSTG(25,24)
ISN 0004      DIMENSION CC(24),CX(24),TINC(24),CSTT(24),GSTT(24),CSI(24),
             *CS2(24),CS3(24),KBPS(24)
ISN 0005      DIMENSION R(9),PA(3,9),QA(3,9),KITLE(10),KODEA(99),KODEB(99),
             *KUNITS(3),NAMX(18),NAMY(18),ITLE(18),BPS(24)
ISN 0006      DIMENSION ICODA(99,10),ICODB(99,10)
ISN 0007      DATA PA /1.11,1.25,1.49,1.23,1.59,2.14,1.37,1.98,2.98,1.51,2.41,
             *3.90,1.63,2.83,4.78,1.76,3.13,5.36,1.85,3.27,5.58,1.92,3.28,
             *5.50,1.96,3.20,5.23/
ISN 0008      READ(5,8000) NCASE
ISN 0009    8000 FORMAT (I5)
ISN 0010      DO 36 I=1,3
ISN 0011      DO 35 J=1,9
ISN 0012     35 QA(I,(10-J))=PA(I,J)
ISN 0013     36 CONTINUE
ISN 0014      DO 9000 ICASE = 1,NCASE
ISN 0015      DO 37 J = 1,90
ISN 0016      KODEA(J) = 0
ISN 0017      KODEB(J) = 0
ISN 0018     37 CONTINUE
ISN 0019     40 READ(5,41) (KITLE(J),J=1,10),KBP,KEP,KPD,KPONS,KPOS,KODEA(1),
             *KODEB(1),NAR,IDPO,ICRV,(KUNITS(I),I=1,3)
ISN 0020     41 FORMAT (10A4,2I2,8X,5I1,I2,2I1,8X,2A4,A2)
ISN 0021      WRITE (6,41) (KITLE(J),J=1,10),KBP,KEP,KPD,KPONS,KPOS,KODEA(1),
             *KODEB(1),NAR,IDPO,ICRV,(KUNITS(I),I=1,3)
ISN 0022      IF (ICRV.LE.0) GO TO 12
ISN 0024     11 READ (5,13) NAMX
ISN 0025      WRITE(6,13) NAMX
ISN 0026      READ (5,13) NAMY
ISN 0027      WRITE(6,13) NAMY
ISN 0028      READ (5,13) ITLE
ISN 0029      WRITE(6,13) ITLE
ISN 0030     13 FORMAT(18A4)
ISN 0031     12 NNN = NAR + 1
ISN 0032      IF (KODEA(1) -0) 60,60,61
ISN 0033     60 IF (KODEB(1)-0) 63,63,61
ISN 0034     61 READ(5,62) (ICODA(1,J),J=1,10),(ICODB(1,J),J=1,10)
ISN 0035     62 FORMAT (10A4,10A4)
ISN 0036     63 IF (NAR-0) 45,45,42
ISN 0037     42 DO 44 I = 2,NNN
ISN 0038      READ(5,43) KODEA(I),KODEB(I)
ISN 0039     43 FORMAT (55X,2I1)
ISN 0040      READ (5,64) (ICODA(I,J),J=1,10),(ICODB(I,J),J=1,10)
ISN 0041     64 FORMAT (10A4,10A4)
ISN 0042     44 CONTINUE
ISN 0043     45 READ (5,46) (R(I),I=1,9)
ISN 0044     46 FORMAT (9F8.3)
ISN 0045     47 IF(IDPO-0) 50,50,48
ISN 0046     48 WRITE (6,8)
ISN 0047      8 FORMAT (1H1///15X,'INPUT DATA'///)
ISN 0048      WRITE(6,49)
ISN 0049     49 FORMAT (2X,'TYPE',2X,'WBS NO.',10X,'NAME',10X,'CODE',7X,
             *'A',10X,'B',10X,'C',10X,'D',9X,'E',4X,'B',2X,'P',2X,'E',
             *1X,'S'///)
ISN 0050     50 N = 0
ISN 0051      NG = 0
ISN 0052     52 KOSTG = 0
ISN 0053      LS = KEP - KBP + 1
ISN 0054    100 N = N + 1
ISN 0055    101 COST(N) = 0
ISN 0056      DO 102 L=1,LS
ISN 0057    102 CST(N,L) = 0
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ISN 0058            K(N,7) = 0
ISN 0059            K(N,6) = 0
ISN 0060          103 READ(5,104) KTP,(K(N,J),J=1,4),(NAME(N,J),J=1,6),KDEA,
                     *KDEB,A,X,B,C,D,KBG,KPK,KEN,KS
ISN 0061          104 FORMAT(I1,4I2,5A4,A3,2I1,4F8.3,F7.3,3I2,I1)
ISN 0062              IF (KTP.EQ.7) GO TO 600
ISN 0064              IF (IDPO-0) 105,105,99
ISN 0065           99 WRITE(6,10)KTP,(K(N,J),J=1,4),(NAME(N,J),J=1,6),KDEA,KDEB,A,X,B,
                     *C,D,KBG,KPK,KEN,KS
ISN 0066           10 FORMAT(6X,I1,1X,3(I2,'.'),I2,1X,5A4,A3,
                     *2I1,1X,4(E8.2,1X),E8.2,   3(1X,I2),1X,I1)
ISN 0067          105 K(N,5)=N
ISN 0068          106 IF(A-0.0) 113,107,113
ISN 0069          107 IF(X-0.0) 113,108,113
ISN 0070          108 IF(B-0.0) 113,109,113
ISN 0071          109 IF(C-0.0) 113,110,113
ISN 0072          110 IF(D-0.0) 113,112,113
ISN 0073          112 KBB = 1
ISN 0074              GO TO 114
ISN 0075          113 KBB = 0
ISN 0076          114 K(N,7) = KBB*100 + KDEA*10 + KDEB
ISN 0077          115 DO 117 I=1,9
ISN 0078              TEMP=I
ISN 0079              TEMP2=TEMP*1.E+03+9.0E+04
ISN 0080              IF (A-TEMP2) 117,116,117
ISN 0081          116 A=R(I)
ISN 0082              GO TO 118
ISN 0083          117 CONTINUE
ISN 0084          118 IF (KTP-9) 122,119,122
ISN 0085          119 NG = NG + 1
ISN 0086              COSTG(NG) = 0
ISN 0087              DO 120 L = 1,LS
ISN 0088          120 CSTG(NG,L) = 0
ISN 0089          121 K(N,6) = NG
ISN 0090              AG(NG) = A
ISN 0091              KX(NG) = X
ISN 0092              KB(NG) = B
ISN 0093              KC(NG) = C

ISN 0094              KD(NG) = D
ISN 0095              KBGG(NG) = KBG
ISN 0096              KPKG(NG) = KPK
ISN 0097              KENG(NG) = KEN
ISN 0098              KSG(NG) = KS
ISN 0099              GO TO 100
ISN 0100          122 DO 124 I=1,9
ISN 0101              TEMP = I
ISN 0102              QQ=TEMP*1.0E+03+9.0E+04
ISN 0103              IF (X-QQ)124,123,124
ISN 0104          123 X=R(I)
ISN 0105              GO TO 125
ISN 0106          124 CONTINUE
ISN 0107          125 DO 127 I=1,9
ISN 0108              TEMP = I
ISN 0109              QQ=TEMP*1.0E+03+9.0E+04
ISN 0110              IF (B-QQ)127,126,127
ISN 0111          126 B=R(I)
ISN 0112              GO TO 129
ISN 0113          127 CONTINUE
ISN 0114          129 IF (KTP-0) 130,100,130
ISN 0115          130 IF (KTP-1) 131,135,131
ISN 0116          131 IF (KTP-2) 132,145,132
ISN 0117          132 IF (KTP-8) 136,145,136
ISN 0118          133 WRITE(6,134) (K(N,L),L=1,4),(NAME(N,J),J=1,6)
ISN 0119          134 FORMAT (1H1//10X,'ERROR IN CARD TYPE ON WBS CARD NO.',2X,
                     *4(I2,'.'),6X,5A4,A3)
ISN 0120              GO TO 100
ISN 0121          135 IF (C-0.) 138,137,138
ISN 0122          137 C = 1.0
ISN 0123          138 CCST = (A * (X**B) *C) + D
ISN 0124              GO TO 165
ISN 0125          136 IF (KTP-3) 133,140,133
ISN 0126          140 CCST = (A*X) + (B*C) + D
ISN 0127              GO TO 165
ISN 0128          145 IF (A-0.0) 150,146,150
ISN 0129          146 IF (X-0.0) 150,147,150
ISN 0130          147 IF (B-0.0) 150,148,150
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ISN 0131        148 IF (C-0.0) 150,149,150
ISN 0132        149 IF (D-0.0) 150,100,150
ISN 0133        150 IF(A-0.0)152,151,152
ISN 0134        151 A=1.0
ISN 0135        152 IF(X-0.0)154,153,154
ISN 0136        153 X=1.0
ISN 0137        154 IF(B-0.0)156,155,156
ISN 0138        155 B=1.0
ISN 0139        156 IF(C-0.0)158,157,158
ISN 0140        157 C=1.0
ISN 0141        158 IF(D-0.0)163,159,163
ISN 0142        159 D=1.0
ISN 0143        163 IF (KTP-2) 430,164,430
ISN 0144        164 CCST = A*X*B*C*D
ISN 0145        165 COST(N) = CCST
ISN 0146        170 IF(KPOS-0)172,100,172
ISN 0147        172 IF (KS-0) 200,100,200
ISN 0148        200 IF (KS-1) 202,201,202
ISN 0149        201 I = 1
ISN 0150            GO TO 210
ISN 0151        202 IF (KS-2) 204,203,204
ISN 0152        203 I=2
ISN 0153            GO TO 210
ISN 0154        204 IF (KS-3) 206,205,206
ISN 0155        205 I=3
ISN 0156            GO TO 210
ISN 0157        206 IF (KS-4) 207,310,207
ISN 0158        207 IF (KS-5) 208,325,208
ISN 0159        208 WRITE(6,209) (K(N,L),L=1,4),(NAME(N,J),J=1,6)
ISN 0160        209 FORMAT (1H1//10X,'ERROR IN COST SPREADING OPTION ON WBS CARD NO.',
                   *2X,4(I2,'.'),6X,5A4,A3)
ISN 0161            GO TO 203
ISN 0162        210 LENGTH = KEN-KBG+1
ISN 0163            MAX = KPK-KBG+1
ISN 0164            ZLNGTH = LENGTH
ISN 0165            FRACT= 1.0/ZLNGTH
ISN 0166            AMAX = MAX
ISN 0167            TP = (AMAX-0.5)*FRACT


ISN 0168        215 IF (TP-0.1) 216,216,217
ISN 0169        216 P = PA(I,1)
ISN 0170            Q = QA(I,1)
ISN 0171            GO TO 234
ISN 0172        217 IF (TP-0.9) 222,218,218
ISN 0173        218 P = PA(I,9)
ISN 0174            Q = QA(I,9)
ISN 0175            GO TO 234
ISN 0176        222 DO 223 KK=1,9
ISN 0177            J = KK
ISN 0178            IF (TP - (0.1*KK)) 225,225,223
ISN 0179        223 CONTINUE
ISN 0180        225 DIFF = TP - (0.1*(J-1))
ISN 0181            PROP = DIFF * 10.0
ISN 0182            DIFFP = PA(I,J) - PA(I,J-1)
ISN 0183            P = PA(I,J-1) +(PROP*DIFFP)
ISN 0184            DIFFQ = QA(I,J) - QA(I,J-1)
ISN 0185            Q = QA(I,J-1)+(PROP*DIFFQ)
ISN 0186        234 SUM = 0
ISN 0187            DO 235 L=1,LENGTH
ISN 0188            ZL=L
ISN 0189            T = (ZL-0.50)*FRACT
ISN 0190            CX(L) = (T**(P-1.0)) * ((1.0-T)**(Q-1.0))
ISN 0191            SUM = SUM + CX(L)
ISN 0192        235 CONTINUE
ISN 0193            DO 238 L=1,LENGTH
ISN 0194            CC(L) =(CX(L)/SUM)* CCST
ISN 0195        238 CONTINUE
ISN 0196        291 IST= KBG - KBP
ISN 0197        292 IF (KOSTG-1) 293,296,293
ISN 0198        293 DO 294 L=1,LENGTH
ISN 0199        294 CST(N,L+IST) = CC(L)
ISN 0200            GO TO 100
ISN 0201        296 DO 297 L=1,LENGTH
ISN 0202        297 CSTG(NG,L+IST) = CC(L)
ISN 0203            GO TO 1240
ISN 0204        310 IF (KEN-0) 311,311,312
ISN 0205        311 KEN = KEP
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ISN 0206        312 LENGTH = KEN-KBG+1
ISN 0207        315 AMOUNT = CCST/LENGTH
ISN 0208            DO 320 L=1,LENGTH
ISN 0209        320 CC(L) = AMOUNT
ISN 0210            GO TO 291
ISN 0211        325 INC=KPK-KBG
ISN 0212            IF (INC) 310,310,326
ISN 0213        326 IF (KEN-0) 330,328,330
ISN 0214        328 KEN=KEP
ISN 0215        330 IFLAT=KEN-KPK+1
ISN 0216            LENGTH = INC + IFLAT
ISN 0217            FINC = INC
ISN 0218            FRACT = 1.0/FINC
ISN 0219            SUM = 0
ISN 0220            DO 350 I=1,INC
ISN 0221            ZI = I
ISN 0222            TINC(I) =(ZI - 0.5)*FRACT
ISN 0223            CX(I) = 1.0 - (2.718**(-4.65*TINC(I)**2.732))
ISN 0224            SUM = SUM + CX(I)
ISN 0225        350 CONTINUE
ISN 0226            FLAT = IFLAT
ISN 0227            SUM = SUM + FLAT
ISN 0228            DO 360 J=1,IFLAT
ISN 0229            CX(INC+J)=1.0
ISN 0230        360 CONTINUE
ISN 0231            DO 370 L=1,LENGTH
ISN 0232            CC(L) = (CX(L)/SUM)*CCST
ISN 0233        370 CONTINUE
ISN 0234            GO TO 291
ISN 0235        430 IF (KS-4) 431,450,431
ISN 0236        431 IF (KS-5) 432,490,432
ISN 0237        432 WRITE(6,209) (K(N,L),L=1,4),(NAME(N,J),J=1,6)
ISN 0238            GO TO 450
ISN 0239        450 AMOUNT = A*X*B*C*D
ISN 0240            IF (KEN-0) 470,460,470
ISN 0241        460 KEN=KEP
ISN 0242        470 LENGTH = KEN-KBG+1
ISN 0243            ZLNGTH = LENGTH

ISN 0244            CCST = ZLNGTH*AMOUNT
ISN 0245            COST(N) = CCST
ISN 0246            DO 480 L=1,LENGTH
ISN 0247            CC(L) = AMOUNT
ISN 0248        480 CONTINUE
ISN 0249            GO TO 291
ISN 0250        490 AMOUNT = A*X*B*C*D
ISN 0251        500 INC = KPK - KBG
ISN 0252            FINC = INC
ISN 0253            IF (KEN-0) 510,502,510
ISN 0254        502 KEN=KEP
ISN 0255        510 IFLAT = KEN-KPK+1
ISN 0256            LENGTH = INC+ IFLAT
ISN 0257        520 FRACT = 1.0/FINC
ISN 0258            DO 530 I=1,INC
ISN 0259            TI=I
ISN 0260            TINC(I) = (TI-0.5)*FRACT
ISN 0261            CX(I) = 1.0 - (2.718**(-4.65*(TINC(I)**2.732)))
ISN 0262        530 CONTINUE
ISN 0263            DO 540 J=1,IFLAT
ISN 0264        540 CX(INC+J) = 1.0
ISN 0265            CCST = 0.0
ISN 0266            DO 560 L=1,LENGTH
ISN 0267            CC(L) = CX(L)*AMOUNT
ISN 0268            CCST = CCST + CC(L)
ISN 0269        560 COST(N) = CCST
ISN 0270            GO TO 291
ISN 0271        600 NC = N - 1
ISN 0272            NGC = NG
ISN 0273            NPRINT = 0
ISN 0274            KODPO = 0
ISN 0275            KOSET = 0
ISN 0276        615 DO 618 N=1,NC
ISN 0277            KT(N,1) = 1000000*K(N,1) + 10000*K(N,2) + 100*K(N,3) + K(N,4)
ISN 0278            KT(N,2) = K(N,5)
ISN 0279            KT(N,4) = K(N,7)
ISN 0280        618 KT(N,3) = K(N,6)
ISN 0281        619 FORMAT (10X,8I12)
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ISN 0282          KP = 0
ISN 0283          N = 0
ISN 0284      620 N = N+1
ISN 0285          IF (N-NC) 622,660,660
ISN 0286      622 IF (KT(N,1)-KT(N+1,1)) 625,650,640
ISN 0287      625 IF (KP-N) 626,620,627
ISN 0288      626 GO TO 620
ISN 0289      627 N=KP
ISN 0290          GO TO 620
ISN 0291      640 KH1 = KT(N,1)
ISN 0292          KH2 = KT(N,2)
ISN 0293          KH3 = KT(N,3)
ISN 0294          KH4=KT(N,4)
ISN 0295          KT(N,1) = KT(N+1,1)
ISN 0296          KT(N,2) = KT(N+1,2)
ISN 0297          KT(N,3) = KT(N+1,3)
ISN 0298          KT(N,4) = KT(N+1,4)
ISN 0299          KT(N+1,1) = KH1
ISN 0300          KT(N+1,2) = KH2
ISN 0301          KT(N+1,3) = KH3
ISN 0302          KT(N+1,4) = KH4
ISN 0303          IF (KP-N) 641,641,642
ISN 0304      641 KP = N
ISN 0305      642 N = N -1
ISN 0306          IF (N-0) 643,643,622
ISN 0307      643 N = 1
ISN 0308          GO TO 622
ISN 0309      650 WRITE (6,651) N
ISN 0310      651 FORMAT (1H1//10X,'ERROR ON WBS CARD NUMBER',I5///)
ISN 0311          WRITE(6,619) (KT(NN,1),NN=1,NC)
ISN 0312          GO TO 620
ISN 0313      660 DO 670 N = 1,NC
ISN 0314          K(N,1) =(KT(N,1))/1000000
ISN 0315          K(N,2) =(KT(N,1)/10000) - K(N,1)*100
ISN 0316          K(N,3) = (KT(N,1)/100) - (K(N,1)*10000) - (K(N,2)*100)
ISN 0317          K(N,4) = KT(N,1)-(K(N,1)*1000000)-(K(N,2)*10000)-(K(N,3)*100)
ISN 0318          K(N,5) = KT(N,2)
ISN 0319          K(N,7) = KT(N,4)


ISN 0320      670 K(N,6) = KT(N,3)
ISN 0321      700 C1 = 0.0
ISN 0322          C2 = 0.0
ISN 0323          C3 = 0.0
ISN 0324          COSTT = 0.0
ISN 0325          IF (KPOS-0) 701,746,701
ISN 0326      701 DO 705 L=1,LS
ISN 0327          CSTT(L) = 0.0
ISN 0328          CS1(L) = 0.0
ISN 0329          CS2(L) = 0.0
ISN 0330      705 CS3(L) = 0.0
ISN 0331      746 K1 = 0
ISN 0332          K2 = 0
ISN 0333          K3 = 0
ISN 0334          K4 = 0
ISN 0335          N = NC + 1
ISN 0336      706 IF (KODPO-0) 1840,710,1840
ISN 0337      710 N = N - 1
ISN 0338      720 IF (N-0) 1200,1200,741
ISN 0339      741 IF (K(N,2)-0) 744,742,750
ISN 0340      742 IF (K(N,3)-0) 744,743,744
ISN 0341      744 WRITE (6,651) N
ISN 0342          WRITE (6,619) (KT(NN,1),NN=1,NC)
ISN 0343      743 IF (K(N,4)-0) 745,1100,745
ISN 0344      745 WRITE (6,651) N
ISN 0345          WRITE (6,619) (KT(NN,1),NN=1,NC)
ISN 0346          GO TO 1100
ISN 0347      750 IF (K(N,3)-0) 751,751,760
ISN 0348      751 IF (K(N,4)-0) 752,1000,650
ISN 0349      752 WRITE (6,651) N
ISN 0350          WRITE (6,619) (KT(NN,1),NN=1,NC)
ISN 0351          GO TO 1000
ISN 0352      760 IF (K(N,4)-0) 900,900,800
ISN 0353      800 C3 = C3 + COST(K(N,5))
ISN 0354          IF (KPOS-0) 801,805,801
ISN 0355      801 DO 802 L=1,LS
ISN 0356      802 CS3(L) = CS3(L) + CST(K(N,5),L)
ISN 0357      805 IF (K(N,3)-K3) 810,811,810
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ISN 0358        810 K1 = K(N,1)
ISN 0359            K2 = K(N,2)
ISN 0360            K3 = K(N,3)
ISN 0361            K4 = K(N,4)
ISN 0362        811 IF (KODPO-1) 710,1840,710
ISN 0363        900 IF (K(N,3)-K3) 940,910,940
ISN 0364        910 COST(K(N,5)) = COST(K(N,5)) + C3
ISN 0365            C2 = C2 + COST(K(N,5))
ISN 0366            C3 = 0.0
ISN 0367            IF (KPOS-0) 920,1143,920
ISN 0368        920 DO 930 L=1,LS
ISN 0369            CST(K(N,5),L) = CST(K(N,5),L) + CS3(L)
ISN 0370            CS2(L) = CS2(L) + CST(K(N,5),L)
ISN 0371        930 CS3(L) = 0.0
ISN 0372            IF (KODPO-1) 710,1840,710
ISN 0373        940 C2 = C2 + COST(K(N,5))
ISN 0374            IF (KPOS - 0) 941,950,941
ISN 0375        941 DO 942 L=1,LS
ISN 0376        942 CS2(L) = CS2(L) + CST(K(N,5),L)
ISN 0377        950 K1 = K(N,1)
ISN 0378            K2 = K(N,2)
ISN 0379            K3 = K(N,3)
ISN 0380            IF (KODPO-1) 710,1840,710
ISN 0381       1000 IF (K(N,2)-K2) 1040,1010,1040
ISN 0382       1010 IF (K(N,4)-0) 1011,1020,1011
ISN 0383       1011 WRITE (6,651) N
ISN 0384            WRITE (6,619) (KT(NN,1),NN=1,NC)
ISN 0385       1020 COST(K(N,5)) = COST(K(N,5)) + C2
ISN 0386            C1 = C1 + COST(K(N,5))
ISN 0387            C2 = 0
ISN 0388            K3 = K(N,3)
ISN 0389            IF(KPOS-0) 1030,1143,1030
ISN 0390       1030 DO 1031 L=1,LS
ISN 0391            CST(K(N,5),L) = CST(K(N,5),L) + CS2(L)
ISN 0392            CS1(L) = CS1(L) + CST(K(N,5),L)
ISN 0393       1031 CS2(L) = 0.0
ISN 0394            IF (KODPO-1) 710,1840,710
ISN 0395       1040 C1 = C1 + COST(K(N,5))

ISN 0396            K1 = K(N,1)
ISN 0397            K2 = K(N,2)
ISN 0398            K3 = K(N,3)
ISN 0399            IF (KPOS-0) 1041,1143,1041
ISN 0400       1041 DO 1042 L=1,LS
ISN 0401       1042 CS1(L) = CS1(L) + CST(K(N,5),L)
ISN 0402            IF (KODPO-1) 710,1840,710
ISN 0403       1100 IF (K(N,1)-K1) 1140,1110,1140
ISN 0404       1110 IF (K3-0) 1111,1120,1111
ISN 0405       1111 WRITE (6,651) N
ISN 0406            WRITE (6,619) (KT(NN,1),NN=1,NC)
ISN 0407       1120 COST(K(N,5)) = COST(K(N,5)) + C1
ISN 0408            COSTT = COSTT + COST(K(N,5))
ISN 0409            C1 = 0
ISN 0410            K1 = K(N,1)
ISN 0411            K2 = K(N,2)
ISN 0412            IF (KPOS-0) 1130,1143,1130
ISN 0413       1130 DO 1131 L = 1,LS
ISN 0414            CST(K(N,5),L) = CST(K(N,5),L) + CS1(L)
ISN 0415            CSTT(L) = CSTT(L) + CST(K(N,5),L)
ISN 0416       1131 CS1(L) = 0
ISN 0417            IF (KODPO-1) 710,1840,710
ISN 0418       1140 COSTT = COSTT + COST(K(N,5))
ISN 0419            K1 = K(N,1)
ISN 0420            K2 = K(N,2)
ISN 0421            K3 = K(N,3)
ISN 0422            IF (KPOS-0) 1141,1143,1141
ISN 0423       1141 DO 1142 L = 1,LS
ISN 0424       1142 CSTT(L) = CSTT(L) + CST(K(N,5),L)
ISN 0425       1143 IF (KODPO-1) 710,1840,710
ISN 0426       1200 IF (NGC-0) 1202,1800,1202
ISN 0427       1202 KOSTG = 1
ISN 0428       1205 DO 1240 NG=1,NGC
ISN 0429       1210 A = AG(NG)
ISN 0430            KBG = KBGG(NG)
ISN 0431            KPK = KPKG(NG)
ISN 0432            KEN = KENG(NG)
ISN 0433            KS = KSG(NG)
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ISN 0434      5100 IF (KX(NG)-0) 1211,5101,1211
ISN 0435      5101 IF (KB(NG)-0) 1211,5102,1211
ISN 0436      5102 IF (KC(NG)-0) 1211,5103,1211
ISN 0437      5103 IF (KD(NG)-0) 1211,5110,1211
ISN 0438      5110 CCST = A * COSTT
ISN 0439           COSTG(NG) = CCST
ISN 0440           IF (KPOS-0) 5120,1240,5120
ISN 0441      5120 IF(KS-0) 200,1240,200
ISN 0442      1211 DO 1217 N=1,NC
ISN 0443           NZ = N
ISN 0444      1212 IF (K(N,1)-KX(NG)) 1217,1213,1217
ISN 0445      1213 IF (K(N,2)-KB(NG)) 1217,1214,1217
ISN 0446      1214 IF (K(N,3)-KC(NG)) 1217,1215,1217
ISN 0447      1215 IF (K(N,4)-KD(NG)) 1217,1220,1217
ISN 0448      1217 CONTINUE
ISN 0449      1220 CCST = A*(COST(K(NZ,5)))
ISN 0450           COSTG(NG) = CCST
ISN 0451      1229 IF (KPOS - 0) 1230,1240,1230
ISN 0452      1230 IF (KS-0) 200,1240,200
ISN 0453      1240 CONTINUE
ISN 0454      1300 GOSTT = 0.0
ISN 0455           DO 1301 L = 1,LS
ISN 0456      1301 GSTT(L) = 0.0
ISN 0457           C1 = 0.0
ISN 0458           C2 = 0.0
ISN 0459           C3 = 0.0
ISN 0460           DO 1305 L = 1,LS
ISN 0461           CS1(L) = 0.0
ISN 0462           CS2(L) = 0.0
ISN 0463      1305 CS3(L) = 0.0
ISN 0464           K1 = 0
ISN 0465           K2 = 0
ISN 0466           K3 = 0
ISN 0467           K4 = 0
ISN 0468           N = NC + 1
ISN 0469      1310 N = N - 1
ISN 0470      1320 IF (N-0) 1341,1770,1341
ISN 0471      1341 IF (K(N,2)-0) 1700,1700,1350

ISN 0472      1350 IF (K(N,3)-0) 1600,1600,1360
ISN 0473      1360 IF (K(N,4)-0) 1500,1500,1400
ISN 0474      1400 IF (K(N,6)-0) 1310,1310,1405
ISN 0475      1405 COST(K(N,5)) = COST(K(N,5)) + COSTG(K(N,6))
ISN 0476      1406 C3 = C3 + COSTG(K(N,6))
ISN 0477           IF (KPOS-0) 1407,1410,1407
ISN 0478      1407 DO 1409 L=1,LS
ISN 0479      1408 CST(K(N,5),L) = CST(K(N,5),L) + CSTG(K(N,6),L)
ISN 0480      1409 CS3(L) = CS3(L) + CSTG(K(N,6),L)
ISN 0481      1410 GO TO 1310
ISN 0482      1500 IF (K(N,6)-0) 1516,1516,1515
ISN 0483      1515 C3 = C3 + COSTG(K(N,6))
ISN 0484      1516 COST(K(N,5)) = COST(K(N,5)) + C3
ISN 0485           C2 = C2 + C3
ISN 0486           C3 = 0.0
ISN 0487           IF (KPOS-0) 1520,1550,1520
ISN 0488      1520 DO 1530 L=1,LS
ISN 0489           IF (K(N,6)-0) 1525,1525,1521
ISN 0490      1521 CS3(L) = CS3(L) + CSTG(K(N,6),L)
ISN 0491      1525 CST(K(N,5),L) = CST(K(N,5),L) + CS3(L)
ISN 0492           CS2(L) = CS2(L) + CS3(L)
ISN 0493      1530 CS3(L) = 0.0
ISN 0494      1550 GO TO 1310
ISN 0495      1600 IF (K(N,6)-0) 1616,1616,1615
ISN 0496      1615 C2 = C2 + COSTG(K(N,6))
ISN 0497      1616 COST(K(N,5)) = COST(K(N,5)) + C2
ISN 0498           C1 = C1 + C2
ISN 0499           C2 = 0.0
ISN 0500           IF (KPOS - 0) 1620,1650,1620
ISN 0501      1620 DO 1630 L=1,LS
ISN 0502           IF (K(N,6)-0) 1626,1626,1625
ISN 0503      1625 CS2(L) = CS2(L) + CSTG(K(N,6),L)
ISN 0504      1626 CST(K(N,5),L) = CST(K(N,5),L) + CS2(L)
ISN 0505           CS1(L) = CS1(L) + CS2(L)
ISN 0506      1630 CS2(L) = 0.0
ISN 0507      1650 GO TO 1310
ISN 0508      1700 IF (K(N,6)-0) 1715,1716,1715
ISN 0509      1715 C1 = C1 + COSTG(K(N,6))
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ISN 0510      1716 COST(K(N,5)) = COST(K(N,5)) + C1
ISN 0511           GOSTT = GOSTT + C1
ISN 0512           C1 = 0.0
ISN 0513           IF (KPOS-0) 1720,1750,1720
ISN 0514      1720 DO 1730 L=1,LS
ISN 0515           IF (K(N,6)-0) 1725,1726,1725
ISN 0516      1725 CSI(L) = CSI(L) + CSTG(K(N,6),L)
ISN 0517      1726 CST(K(N,5),L) = CST(K(N,5),L) + CSI(L)
ISN 0518           GSTT(L) = GSTT(L) + CSI(L)
ISN 0519      1730 CSI(L) = 0.0
ISN 0520      1750 GO TO 1310
ISN 0521      1770 COSTT = COSTT + GOSTT
ISN 0522           IF (KPOS-0) 1771,1800,1771
ISN 0523      1771 DO 1772 L=1,LS
ISN 0524      1772 CSTT(L) = CSTT(L) + GSTT(L)
ISN 0525      1800 IF(KODEA(1)-0)1805,1801,1805
ISN 0526      1801 IF(KODEB(1)-0)1805,2000,1805
ISN 0527      1805 KODPO=1
ISN 0528      1810 KOSTG=0
ISN 0529      1820 II = NPRINT+1
ISN 0530           DO 1821 N = 1,NC
ISN 0531           IF ((K(N,7)/100)-0) 1821,1821,1822
ISN 0532      1822 COST(K(N,5)) = 0.0
ISN 0533           IF (KPOS-1) 1821,1823,1823
ISN 0534      1823 DO 1824 L = 1,LS
ISN 0535      1824 CST(K(N,5),L) = 0.0
ISN 0536      1821 CONTINUE
ISN 0537      1835 GO TO 700
ISN 0538      1840 N=N-1
ISN 0539           IF(N-0)1845,2000,1845
ISN 0540      1845 K88 = K(N,7)/100
ISN 0541           KDEA=(K(N,7)-(K88*100))/10
ISN 0542           KDEB=K(N,7)-(K88*100)-(KDEA*10)
ISN 0543      1850 NP=K(N,5)
ISN 0544           IF(K88-1)1866,1880,1866
ISN 0545      1866 IF(KODEA(II)-0) 1867,1868,1867
ISN 0546      1867 IF(KDEA-KODEA(II))1870,1868,1870
ISN 0547      1868 IF(KODEB(II)-0)1869,1880,1869

ISN 0548      1869 IF(KDEB-KODEB(II))1870,1880,1870
ISN 0549      1870 IF(K88-1)1890,1880,1890
ISN 0550      1880 K(N,6)=1
ISN 0551      1885 GO TO 741
ISN 0552      1890 K(N,6)=0
ISN 0553      1891 GO TO 1840
ISN 0554      2000 IF (KDSET-0) 2201,2001,2201
ISN 0555      2001 KDSET = KDSET + 1
ISN 0556      2004 IF (KPOS-0) 2003,2003,2002
ISN 0557      2002 KSP = 1
ISN 0558           GO TO 2100
ISN 0559      2003 KSP = 0
ISN 0560      2100 IF (KPD-0) 2110,2201,2110
ISN 0561      2110 IF (KPD-1) 2120,2282,2120
ISN 0562      2282 COSTT = COSTT/10.0
ISN 0563           DO 2283 N=1,NC
ISN 0564      2283 COST(N) = COST(N)/10.0
ISN 0565           IF (KSP-1) 2201,2284,2201
ISN 0566      2284 DO 2286 L=1,LS
ISN 0567           CSTT(L) = CSTT(L)/10.0
ISN 0568           DO 2285 N=1,NC
ISN 0569      2285 CST(N,L) = CST(N,L)/10.0
ISN 0570      2286 CONTINUE
ISN 0571           GO TO 2201
ISN 0572      2120 IF (KPD-2) 2130,2297,2130
ISN 0573      2297 COSTT = COSTT/100.0
ISN 0574           DO 2298 N=1,NC
ISN 0575      2298 COST(N) = COST(N)/100.0
ISN 0576           IF (KSP-1) 2201,2299,2201
ISN 0577      2299 DO 2301 L=1,LS
ISN 0578           CSTT(L) = CSTT(L)/100.0
ISN 0579           DO 2300 N=1,NC
ISN 0580      2300 CST(N,L) = CST(N,L)/100.0
ISN 0581      2301 CONTINUE
ISN 0582           GO TO 2201
ISN 0583      2130 IF (KPD-3) 2140,2312,2140
ISN 0584      2312 COSTT = COSTT/(1000.0)
ISN 0585           DO 2313 N=1,NC
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ISN 0586      2313 COST(N) = COST(N)/1000.0
ISN 0587           IF (KSP-1) 2201,2314,2201
ISN 0588      2314 DO 2316 L=1,LS
ISN 0589           CSTT(L) = CSTT(L)/1000.0
ISN 0590           DO 2315 N=1,NC
ISN 0591      2315 CST(N,L) = CST(N,L)/1000.0
ISN 0592      2316 CONTINUE
ISN 0593           GO TO 2201
ISN 0594      2140 IF (KPO-5) 2150,2327,2150
ISN 0595      2327 COSTT = COSTT/100000.0
ISN 0596           DO 2328 N=1,NC
ISN 0597      2328 COST(N) = COST(N)/100000.0
ISN 0598           IF (KSP-1) 2201,2329,2201
ISN 0599      2329 DO 2331 L=1,LS
ISN 0600           CSTT(L) = CSTT(L)/100000.0
ISN 0601           DO 2330 N=1,NC
ISN 0602      2330 CST(N,L) = CST(N,L)/100000.0
ISN 0603      2331 CONTINUE
ISN 0604           GO TO 2201
ISN 0605      2150 IF (KPO-6) 2201,2342,2201
ISN 0606      2342 COSTT = COSTT/1000000.0
ISN 0607           DO 2343 N=1,NC
ISN 0608      2343 COST(N) = COST(N)/1000000.0
ISN 0609           IF (KSP-1) 2201,2344,2201
ISN 0610      2344 DO 2346 L=1,LS
ISN 0611           CSTT(L) = CSTT(L)/1000000.0
ISN 0612           DO 2345 N=1,NC
ISN 0613      2345 CST(N,L) = CST(N,L)/1000000.0
ISN 0614      2346 CONTINUE
ISN 0615      2201 IF (KPOS-0) 2202,2205,2202
ISN 0616      2202 KSP = 1
ISN 0617           GO TO 2220
ISN 0618      2205 IF (KPONS-0) 2208,2206,2208
ISN 0619      2206 GO TO 3000
ISN 0620      2208 KSP = 0
ISN 0621      2220 LC = 0
ISN 0622           WRITE (6,2225) KITLE
ISN 0623      2225 FORMAT (//1H1/,24X,10A4///)

ISN 0624           LC = LC + 6
ISN 0625           IF (KODPO-1) 2260,2236,2260
ISN 0626      2236 WRITE (6,2237) KODEA(II),(ICODA(II,J),J=1,10),KODEB(II),
                  *(ICODB(II,J),J=1,10)
ISN 0627      2237 FORMAT (11X,'THIS PRINTOUT COVERS COST CODES:'/11X,'CODE A = '
                  *,I1,', ',10A4/11X,'CODE B = ',I1,', ',10A4//)
ISN 0628           LC = LC + 6
ISN 0629      2260 IF (KPO-0) 2275,2265,2275
ISN 0630      2265 WRITE (6,2270)
ISN 0631      2270 FORMAT (/)
ISN 0632           GO TO 2350
ISN 0633      2275 IF (KPO-1) 2290,2280,2290
ISN 0634      2280 WRITE (6,2281)
ISN 0635      2281 FORMAT (79X 'TENS OF')
ISN 0636      2289 GO TO 2350
ISN 0637      2290 IF (KPO-2) 2305,2295,2305
ISN 0638      2295 WRITE (6,2296)
ISN 0639      2296 FORMAT (76X,'HUNDREDS OF')
ISN 0640      2304 GO TO 2350
ISN 0641      2305 IF (KPO-3) 2320,2310,2320
ISN 0642      2310 WRITE (6,2311)
ISN 0643      2311 FORMAT (76X,'THOUSANDS OF')
ISN 0644      2319 GO TO 2350
ISN 0645      2320 IF (KPO-5) 2335,2325,2335
ISN 0646      2325 WRITE (6,2326)
ISN 0647      2326 FORMAT (71X,'HUNDREDS OF THOUSANDS OF')
ISN 0648      2334 GO TO 2350
ISN 0649      2335 IF (KPO-6) 2265,2340,2265
ISN 0650      2340 WRITE (6,2341)
ISN 0651      2341 FORMAT (76X,'MILLIONS OF')
ISN 0652      2350 WRITE (6,2351) KUNITS
ISN 0653      2351 FORMAT (11X,'WBS NUMBER',18X,'ITEM',35X, 2A4,A2  /'+',10X,
                  *'___ ______',18X,'____',35X,'_______.'//)
ISN 0654           LC = LC + 3
ISN 0655      2250 IF (KSP-1) 2352,2251,2352
ISN 0656      2251 WRITE (6,2252)
ISN 0657      2252 FORMAT (12X,'(PERIOD NO.)')
ISN 0658           LC = LC + 1
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ISN 0659      2355 DO 2356 L=1,LS
ISN 0660           KBPS(L) = KBP + L - 1
ISN 0661      2356 BPS(L) = KBPS(L)
ISN 0662      2362 IF (LS-8) 4000,4000,4005
ISN 0663      4000 WRITE (6,4001) (KBPS(L),L=1,LS)
ISN 0664      4001 FORMAT(12X,8('(',I2,')',7X))
ISN 0665           LC = LC + 2
ISN 0666           KSPD = 1
ISN 0667           GO TO 5000
ISN 0668      4005 IF (LS-16) 4010,4010,4020
ISN 0669      4010 WRITE(6,4006) (KBPS(L),L=1,8)
ISN 0670      4006 FORMAT(12X,8('(',I2,')',7X))
ISN 0671           WRITE (6,4006) (KBPS(L),L=9,LS)
ISN 0672           LC = LC + 4
ISN 0673           KSPD = 2
ISN 0674           GO TO 5000
ISN 0675      4020 WRITE (6,4006) (KBPS(L),L=1,8)
ISN 0676      4025 WRITE (6,4006) (KBPS(L),L=9,16)
ISN 0677      4030 WRITE (6,4006) (KBPS(L),L=17,LS)
ISN 0678           LC = LC + 6
ISN 0679           KSPD = 3
ISN 0680      5000 WRITE (6,2364) COSTT
ISN 0681      2364 FORMAT(//24X,'PROGRAM TOTAL',25X,F12.1/'+',23X,50('_'))
ISN 0682           LC = LC + 2
ISN 0683           WRITE (6,2365) (CSTT(L),L=1,LS)
ISN 0684      2365 FORMAT (4X,8F11.1)
ISN 0685           IF(ICRV.LE.0) GO TO 2376
ISN 0687           CALL GRAPH(1,42,-LS,BPS,CSTT,NAMX,NAMY,ITLE)
ISN 0688           GO TO 2376
ISN 0689      2352 WRITE (6,2353) COSTT
ISN 0690      2353 FORMAT (24X,'PROGRAM TOTAL',21X,F12.1/'+',23X,46('_'))
ISN 0691           LC = LC + 1
ISN 0692           GO TO 2380
ISN 0693      2376 IF (KPOS-1) 2377,2384,2377
ISN 0694      2377 IF (KPOS-2) 2378,2385,2378
ISN 0695      2378 IF (KPOS-3) 2379,2386,2379
ISN 0696      2379 IF (KPOS-4) 2387,2387,2387
ISN 0697      2380 IF (KPONS-1) 2381,2384,2381

ISN 0698      2381 IF (KPONS-2) 2382,2385,2382
ISN 0699      2382 IF (KPONS-3) 2383,2386,2383
ISN 0700      2383 IF (KPONS-4) 2387,2387,2387
ISN 0701      2384 LEV = 1
ISN 0702           GO TO 2400
ISN 0703      2385 LEV = 2
ISN 0704           GO TO 2400
ISN 0705      2386 LEV = 3
ISN 0706           GO TO 2400
ISN 0707      2387 LEV = 4
ISN 0708      2400 DO 2930 N=1,NC
ISN 0709           IF (KODPO-1) 2405,2401,2405
ISN 0710      2401 IF(K(N,6)-1) 2930,2402,2930
ISN 0711      2402 IF((K(N,7)/100) - 1) 2405,2403,2405
ISN 0712      2403 IF (COST(K(N,5))-0.0) 2405,2930,2405
ISN 0713      2405 NP = K(N,5)
ISN 0714      2410 IF (K(N,2)-0) 2470,2470,2411
ISN 0715      2411 IF (K(N,3)-0) 2412,2412,2413
ISN 0716      2412 IF (LEV-2) 2930,2550,2550
ISN 0717      2413 IF (K(N,4)-0) 2414,2414,2415
ISN 0718      2414 IF (LEV-3) 2930,2650,2650
ISN 0719      2415 IF (LEV-4) 2930,2755,2755
ISN 0720      2470 IF (KSP-1) 2471,2472,2472
ISN 0721      2471 WRITE (6,2480)(K(N,I),I=1,4),(NAME(NP,J),J=1,6),COST(NP)
ISN 0722      2480 FORMAT (//10X,3(I2,'.'),I2,3X,5A4,A3,11X,F17.1)
ISN 0723           LC = LC + 3
ISN 0724           GO TO 6000
ISN 0725      2472 LC = LC + 3 + KSPD
ISN 0726           IF ( LC-39) 2473,2474,2474
ISN 0727      2474 WRITE (6,2475)
ISN 0728      2475 FORMAT (1HI)
ISN 0729           LC = 3 + KSPD
ISN 0730      2473 WRITE (6,2481) (K(N,I),I=1,4),(NAME(NP,J),J=1,6),COST(NP)
ISN 0731      2481 FORMAT(//10X,3(I2,'.'),I2,3X,5A4,A3,11X,F12.1/'+', 9X,60('_'))
ISN 0732      2510 WRITE (6,2511) (CST(NP,L),L=1,LS)
ISN 0733      2511 FORMAT (5X,8F11.1)
ISN 0734      2515 GO TO 2930
ISN 0735      2550 IF (KSP-1) 2551,2552,2552
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ISN 0736      2561 WRITE (6,2560) (K(N,L),L=2,4),(NAME(NP,J),J=1,6),COST(NP)
ISN 0737      2560 FORMAT (/13X,2(I2,'.'),I2,6X,5A4,A3,17X,F12.1)
ISN 0738           LC = LC + 2
ISN 0739           GO TO 6000
ISN 0740      2552 LC = LC + 2 + KSPD
ISN 0741           IF (LC-38) 2553,2554,2554
ISN 0742      2554 WRITE (6,2475)
ISN 0743           LC = 2 + KSPD
ISN 0744      2553 WRITE (6,2561) (K(N,I),I=1,4),(NAME(NP,J),J=1,6),COST(NP)
ISN 0745      2561 FORMAT( /10X,3(I2,'.'),I2,6X,5A4,A3,17X,F12.1/'+', 9X,69('_'))
ISN 0746           WRITE (6,2511) (CST(NP,L),L=1,LS)
ISN 0747      2545 GO TO 2930
ISN 0748      2650 IF (KSP-1) 2651,2652,2652
ISN 0749      2651 WRITE(6,2660) (K(N,I),I=3,4),(NAME(NP,J),J=1,6),COST(NP)
ISN 0750      2660 FORMAT ( 16X,I2,'.',I2,9X,5A4,A3,23X,F12.1)
ISN 0751           LC = LC + 1
ISN 0752           GO TO 6000
ISN 0753      2652 LC = LC + 2 + KSPD
ISN 0754           IF (LC-38) 2653,2654,2654
ISN 0755      2654 WRITE (6,2475)
ISN 0756           LC = 2 + KSPD
ISN 0757      2653 WRITE (6,2661) (K(N,I),I=1,4),(NAME(NP,J),J=1,6),COST(NP)
ISN 0758      2661 FORMAT( /10X,3(I2,'.'),I2,9X,5A4,A3,23X,F12.1/'+', 9X,78('_'))
ISN 0759           WRITE (6,2511) (CST(NP,L),L=1,LS)
ISN 0760      2695 GO TO 2930
ISN 0761      2755 IF (KSP-1) 2756,2757,2757
ISN 0762      2756 WRITE(6,2760) K(N,4),(NAME(NP,J),J=1,6),COST(NP)
ISN 0763      2760 FORMAT (19X,I2,12X,5A4,A3,29X,F12.1)
ISN 0764           LC = LC + 1
ISN 0765           GO TO 6000
ISN 0766      2757 LC = LC + 2 + KSPD
ISN 0767           IF (LC-38) 2758,2759,2759
ISN 0768      2759 WRITE (6,2475)
ISN 0769           LC = 2 + KSPD
ISN 0770      2758 WRITE (6,2761) (K(N,I),I=1,4),(NAME(NP,J),J=1,6),COST(NP)
ISN 0771      2761 FORMAT( /10X,3(I2,'.'),I2,12X,5A4,A3,29X,F12.1/'+', 9X,87('_'))
ISN 0772           WRITE (6,2511) (CST(NP,L),L=1,LS)
ISN 0773           GO TO 2930


ISN 0774      6000 IF (LC-38) 2930,6001,6001
ISN 0775      6001 WRITE(6,6002)
ISN 0776      6002 FORMAT (1H1)
ISN 0777           LC = 0
ISN 0778      2930 CONTINUE
ISN 0779      2940 IF (KSP-1) 2950,2205,2950
ISN 0780      2950 NPRINT = NPRINT + 1
ISN 0781      2960 IF (NPRINT-(NAR+1)) 1805,3000,1805
ISN 0782      3000 WRITE (6,3001)
ISN 0783      3001 FORMAT (1H1)
ISN 0784           WRITE(6,3002)(KTITLE(J),J=1,10)
ISN 0785      3002 FORMAT (//10X,10A4)
ISN 0786           WRITE(6,3004)                    *KBP,KEP,KPD,KPONS,KPOS,KODEA(1),
                  *KODEB(1),NAR
ISN 0787      3004 FORMAT (          12X,'KBP=',I5,2X,'KEP=',I5,2X,'KPD=',I5,2X,
                  *'KPONS=',I5/12X,'KPOS=',I5,2X,'KODEA=',I5,2X,'KODEB=',I5,2X,'NAR='
                  *,I5//)
ISN 0788           WRITE(6,3003) (P(I),I=1,9)
ISN 0789      3003 FORMAT (10X,'THE RATES USED ARE:'/15X,5E12.3/15X,4E12.3)
ISN 0790           NAR = NAR + 1
ISN 0791           WRITE (6,3300)
ISN 0792      3300 FORMAT (/10X,'THE CODES USED ARE:'/10X,'A = ')
ISN 0793           WRITE(6,3005) (KODEA(I),I=1,NNN)
ISN 0794      3005 FORMAT(10X,30I3)
ISN 0795           WRITE (6,3400)
ISN 0796      3400 FORMAT (/10X,'B = ')
ISN 0797           WRITE(6,3005) (KODEB(I),I=1,NNN)
ISN 0798      9000 CONTINUE
ISN 0799           STOP
ISN 0800           END
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